Forging new directions in physics education in Australian universities

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2009
Names of the universities involved
Curtin University of Technology
CQ University
Edith Cowan University
Flinders University
Griffith University
La Trobe University
Macquarie University
Monash University
Murdoch University
Queensland University of Technology
RMIT University
Swinburne University of Technology
The Australian National University
The University of Adelaide
The University of Melbourne
The University of New South Wales
The University of Queensland
The University of Sydney
The University of Western Australia
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University of Newcastle
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Project website
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Executive Summary

**Purpose, goals and outcomes**

The purpose of the project was to extend three strategic areas of major concern identified in our previous AUTC-funded work *Learning Outcomes and Curriculum Development in Physics* [1].

In the first area, we aimed to illuminate what constitutes good practice in physics *Service Teaching* and to identify and disseminate such practice. By engaging the wider academic and professional communities, we aimed to strengthen traditional partnerships and create new and productive alliances. Outcomes of this strand of the project include the classification of models of service teaching and their characteristic features [2]. A paper-based survey instrument has been developed to probe students’ expectations and experiences within a service subject. 7500 student responses to these surveys, across 35 subjects in 22 institutions [3], have been analysed. From the data we have identified subjects which have been particularly successful at realising students’ high expectations. These have been showcased at a national workshop and details placed on the project website [4]. An issue of national significance that has emerged from the study is the need for urgent reconsideration of the laboratory experience of students within service subjects.

The second area, *Undergraduate Experimentation*, occurs in almost all undergraduate physics courses and accounts for 30% or more of contact time for students. It generally has the highest staff to student ratio of any teaching/learning activity and therefore is expensive but has great potential for student learning. Despite its prevalence, there are indications that the potential of laboratory learning is not fully realised [5]. We aimed to investigate effective undergraduate laboratory learning environments and engage the community in developing sustainable research-based teaching practices. Outcomes include the identification and successful trialling of the Advancing Chemistry by Enhancing Learning in the Laboratory (ACELL) approach to evaluating and improving laboratory experiments in physics, and the establishment of a readily accessible repository of second and third year experiments.

The third area, *Graduates in the Workforce*, is an on-going issue as course designers act to meet the challenge of aligning graduate attributes with employer expectations and providing valid employment information to students. We aimed to identify graduate destinations and employer expectations and explore the suitability of current course learning outcomes, content, structures and learning activities. A survey was developed and administered utilising the SurveyMonkey online hosting site. We received responses from more than one hundred and seventy physics graduates and ten employers. Follow-up emails to selected respondents collected more in-depth data and have been used to generate profiles of physics graduates in the workforce. These profiles are hosted on the project website [www.physics.usyd.edu.au/super/ALTC/](http://www.physics.usyd.edu.au/super/ALTC/).

Five national workshops were among the key dissemination events that took place during this project. Outcomes of the workshops included consolidation and extension of the established network of physics educators as well as extensive networking with the Australian Council of the Deans of Science (ACDS) and the ACELL project groups.
Recommendations

This project has revealed issues deserving consideration by specific groups within the physics community, including heads of departments and subject coordinators. Below we articulate six main recommendations. The recommendations are designed to exploit the insights we have gained, and to encourage the embedding and sustaining of the several initiatives arising from this project.

1. **For the consideration of the Australian Institute of Physics (AIP)**

To take over, manage and maintain the project website to the benefit of physics graduates, the tertiary physics education community and the wider Australian physics community. This management would include collecting and collating further resources such as graduate destinations and profiles and expanding the repository of physics experiments.

2. **For the consideration of the Australian tertiary physics community**

To recognise that the laboratory experience of students in first year physics subjects (including service subjects) across the majority of the tertiary physics institutions in Australia is a matter of concern, demanding urgent action. As similar issues have been identified by the Australian Council of the Deans of Science (ACDS) in their broader consideration of laboratory work across a range of science disciplines, it is important for the physics community continue to liaise closely with the ACDS to enhance learning outcomes for students in undergraduate physics laboratories.

3. **For the consideration of Australian Learning and Teaching Council (ALTC)**

To support initiatives that explore, identify and disseminate good practice in undergraduate laboratories for students enrolled in physics subjects and initiatives that address issues such as professional development and on-going support for casual teaching staff.

4. **For the consideration of co-ordinators or convenors of physics service subjects**

To administer and process the expectations/experiences surveys over a period of time, in order to identify, track and respond to issues relating to physics service teaching.

5. **For the consideration of subject co-ordinators of senior physics subjects**

To continue to supply details of experiments at second and third year levels in order to enhance the breadth and value of the repository hosted on the project website, to the benefit of the Australian tertiary physics community.

6. **For the consideration of heads of departments (HODs) or nominees**

To take steps to enhance their knowledge of the graduate destinations of the full range of their own graduates and to continue to supply this information to the AIP in order that the project webpage devoted to this issue remain current, relevant, and representative.
A vision for the discipline

Physics is an essential enabling discipline underpinning modern technology, lifestyle, the national economic strength and one which makes a vital contribution to issues of global significance, such as climate change. The vision of university physics education is to:

- attract students to physics;
- provide the best physics education;
- strengthen physics and multidisciplinary (associated) research and development;
- stimulate individuals to engage with the physics around them and utilise physics-based knowledge and skills in their professional careers; and
- imbue the next generation of physicists with the capacity to work towards solving problems that are both applied and fundamental in nature, to the benefit of society nationally and globally.
Investigation strategy

The 2004/5 AUTC-funded study Learning Outcomes and Curriculum Development in Physics established baseline data from all 34 universities that had a discernable physics department or group. In-depth studies were carried out across nine institutions specifically targeted to capture the diversity in terms of geographic location and teaching and research activities. Furthermore, an extensive and strong collective was established drawing on the Physics Education Group (PEG) of the Australian Institute of Physics (AIP). A range of areas that could benefit from further work was identified. From these, the following three critical areas were pursued through this project:

Service Teaching
Illuminating good practice in service teaching.

Undergraduate Experimentation
Developing and sustaining research-based teaching methodologies.

Graduates in the Workforce
Exploring the diverse employment opportunities for physics graduates.

The reasons for choosing these areas of physics:

1. Service teaching is critical for at least two reasons. First, large first year service subjects provide significant income for physics departments and second, the large numbers of students are ambassadors for physics in schools, industry, business and politics.

2. Undergraduate experimentation is resource intensive and yet it continues to constitute 30% or more of staff-student contact time. The opportunity to transform learning in laboratories into a valuable experience needs to be realised, not only in physics, but across the sciences.

3. To market physics to teachers and prospective students and to maintain student numbers, it is critical to understand where physics graduates find employment and their experiences in the workplace. We need to understand that we are preparing graduates for the diverse workplace, which in itself is a challenge as it is difficult to track graduates. For more details see the AUTC report [1].

Each area presents a different challenge in terms of teaching and learning. With service teaching, motivation and the need to connect with the students’ professional inclinations is a precursor to engagement and learning [9]. With undergraduate experimentation, two aspects are paramount: the need to balance technical skills with creativity and having adequate support from demonstrators [10]. Trying to unravel which learning experiences contribute to graduate skills and workplace requirements for the diverse range of jobs is a challenge. Furthermore, the question “to what extent does discipline-based education contribute to what is valued by employers?” consistently emerged from our studies [11].

A working party was assembled for each area. Each working party had different anticipated outcomes and consequently developed individual investigation
strategies to meet those outcomes. The number of people in each working party has grown over time. The members by the end of the project were as follows:

**Service Teaching Working Party**
Leader: Les Kirkup (UTS)
Team members: David Low (UNSW@ADFA), Richard Metcalfe (CQU), Evan Gray (Griffith), Narelle Brack, David Hoxley, Svetlana Petelina (La Trobe), Michelle Livett (Melbourne), Chris Creagh (Murdoch), David Lamb, James Buick (UNE), Anton Rayner (Queensland), Alex Mazzolini, Owen Shepherd (Swinburne), Simon Housego (UTS), Stephen Collins (VU), Ragbir Bhathal (UWS)

**Undergraduate Experimentation Working Party**
Leader: Kate Wilson (ANU), with David Mills (Monash) acting leader January-July 2008 while KW on maternity leave
Team members: Geoff Swan (ECU), Jamie Quinton (Flinders), Robert Sang (Griffith), James Downes (Macquarie), Kate Barnard (Melbourne), Michael Gladys, Marian Radny (Newcastle), Margaret Wegener (Queensland), Darren Pearce (QUT), Nicholas Ekins-Daukes (Sydney), Annette Dowd (UTS), Peter Hammond (UWA)

**Graduates in the Workforce Working Party**
Leader: John O’Byrne (Sydney)
Team members: Judith Pollard (Adelaide), Patrick Keleher (Central Queensland), Marjan Zadnik (Curtin), Richard Newbury (UNSW), Alex Merchant (RMIT), Cuong Ton-That, Michael Braun (UTS), Bill Zealey (Wollongong)

A project officer carried out the day-to-day operation of the three working parties. For the first half of the project Dale Scott held this position and for the second half the position was held by Alberto Mendez. We have had project contact persons from 26 universities spread across the three working parties. The project contact persons committed themselves to a particular working party but, when needed, contributed to the other working parties. The project leaders, project officers and working party team members have had regular communication by email, phone and through the workshops. The regular communication and workshops meant that, despite having three somewhat disparate working parties, the project has adopted an integrated approach to actions and dissemination.

**Service teaching**
**Preamble**
Our goal in the service teaching strand of this project was to reach consensus about what constitutes good practice in service teaching in physics, identify such practice in Australian universities and disseminate the findings through workshops involving physics academics, contact with discipline leaders (such as physics heads of departments (HODs) and the Australian Council of the Deans of Science (ACDS)), a website and papers presented at national conferences.

Through service teaching, the tertiary physics community in Australia reaches many thousands of students each year. Physics service subjects have a key role to play in the development of graduate capabilities such as the capacity to learn in, and from, new disciplines in order to enhance the application of scientific knowledge and skills in professional contexts.
Students in service subjects carry with them their experiences of physics, which affects the esteem with which physics is held by an influential community of university-educated citizens. Other reasons for concentrating on physics service teaching include acknowledging the growing importance of contributions that physics makes to other disciplines (such as engineering and other branches of the physical sciences) and the fact that the financial well-being of most Australian physics departments is tied to their service teaching.

This study brought an emphasis to the student voice, as we explored what is meant by good practice in service teaching, where such practice is occurring, and the key factors that allow good practices to flourish within a physics department. In particular, we were keen to examine the question what impact does a semester of physics have on students not intending to major in physics? Through a consideration of students’ expectations and experiences of service subjects, we were intent on identifying and promoting indicators of good practice.

Strategies – developing, trialling and broadening student surveys
Characterising current models of teaching to non-physics majors (NPMs)
We began our consideration of physics service teaching by canvassing members of the service teaching working party and some heads of departments about the current state of service teaching within their universities. The purpose of this was to obtain an up-to-date snap-shot of current practices in a diversity of institutions which would inform an analysis of the types of physics service subjects extant in Australian universities. We were also anticipating that, since the AUTC study on ‘Learning Outcomes and Curriculum Development in Physics’ [1], changes might have occurred in some institutions as a consequence of staff reductions and the resulting consolidation of subjects.

Subjects enrolling non-physics majors are diverse. In order to reasonably assess that diversity we collated material from 42 physics subjects across 12 universities, representing institutions in New South Wales (3), Queensland (3), Victoria (2), the ACT (2), and Western Australia (2). The materials reviewed included subject/unit outlines for all subjects, lab manuals for 21 subjects and assignments/exams for 20 subjects.

What constitutes good service teaching?
We considered this from three perspectives:

1. The general literature of good practice in university teaching: by reviewing monographs, peer-reviewed papers and online articles such as those found on webpages allied to ‘Centres of Learning and Teaching’ (or equivalent).

2. To bring a physics focus to the matter of good practice in service teaching, we sought the insights of physics academics who are engaged in service teaching. To this end and in order to establish an informed consensus with respect to what constitutes good practice in service teaching, we canvassed physics academics with contemporary experience of such teaching on the question “what constitutes good practice in teaching a subject designed for non-physics majors?” 25 academics from 12 universities attending a project workshop in 2007 were asked to propose indicators of good practice and to distinguish, if possible, between general good practice and that which is of special relevance to service teaching. The working party leader, project officer and members of the working party subsequently reviewed the responses and ranked the indicators based on
the frequency with which each was mentioned by an individual at the workshop.

3. We listened to students. Guided by the outcomes of identifying and ranking indicators of good practice in service teaching, we devised two student surveys. The first included questions aimed at revealing student expectations of the subject with regard to links being made between physics and their chosen (or intended) major. The second survey was designed to reveal whether their experiences of the subject, over the course of the semester in which they were enrolled in the subject, matched their expectations.

In surveying students we wished to establish the impact of a single semester of physics on students destined to major in disciplines other than physics. A prototype survey was devised and trialled to uncover expectations and experiences of non-physics majors enrolled in a first year physics subject. In order to assist the development of the survey, we trialled the surveys on bio/medical science majors at a large metropolitan university. We wished to:

• explore student views of the value of physics to their major area of study,
• determine whether those views were transformed over the course of the semester,
• examine themes relating to service teaching which might provide direction for a larger survey and have relevance on a national level,
• establish the extent to which students expected links to be made between the physics they studied and the discipline in which they were (or were likely to be) majoring,
• provide points of comparison, for example on laboratory experiences, with the same surveys to be administered nationally,
• revise the surveys (if appropriate) in the light of student responses (for example, in order to improve clarity).

The prototype survey was administered and themes identified. The survey was modified as a result of reviewing responses as well as comments from teaching and learning specialists. The questions included in the final (revised) surveys are given in Table 1.
<table>
<thead>
<tr>
<th>Survey A (expectations)</th>
<th>Survey B (experiences)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q1 It is apparent to me that this subject is a valuable part of my degree.</td>
<td>It is apparent to me that this subject is a valuable part of my degree.</td>
</tr>
<tr>
<td>Q2 Only people with an extraordinary ability are capable of understanding physics.</td>
<td>Only people with an extraordinary ability are capable of understanding physics.</td>
</tr>
<tr>
<td>Q3 I am keen to see how this subject links to my major area of study.</td>
<td>I am able to appreciate the links between this subject and my major area of study.</td>
</tr>
<tr>
<td>Q4 I believe an understanding of physics will benefit my studies in other areas of my degree.</td>
<td>I believe an understanding of physics will benefit my studies in other areas of my degree.</td>
</tr>
<tr>
<td>Q5 I am confident that my mathematics background is sufficient for me to be successful in this subject.</td>
<td>I believe my mathematics background was sufficient for me to be successful in this subject.</td>
</tr>
<tr>
<td>Q6 I expect to do well in class tests in this subject.</td>
<td>My achievements in class tests in this subject exceeded my expectations.</td>
</tr>
<tr>
<td>Q7 I am looking forward to doing labs in this subject.</td>
<td>The labs in this subject were a positive learning experience.</td>
</tr>
<tr>
<td>Q8 If it were possible, I would have avoided taking this subject.</td>
<td>I would advise others to avoid taking this subject if at all possible.</td>
</tr>
<tr>
<td>Q9 I expect the links between this subject and my major area of study to be made obvious throughout the semester.</td>
<td>The lecturers succeeded in linking this subject to my major area of study.</td>
</tr>
<tr>
<td>Q10 I expect to have to work harder in this subject than in my other subjects this semester.</td>
<td>I worked harder in this subject than for my other subjects this semester.</td>
</tr>
<tr>
<td>Q11 What final grade are you aiming for in this subject?</td>
<td>What final grade are you aiming for in this subject?</td>
</tr>
<tr>
<td>Q12 Did you study physics to year 12 at school?</td>
<td>Did you study physics to year 12 at school?</td>
</tr>
<tr>
<td>Q13 <strong>Open-ended question</strong>: Please describe briefly any particular expectations you have as you begin your study in this subject.</td>
<td><strong>Open-ended question</strong>: Please describe briefly your experience of this subject, and in particular what you think might be done to improve the subject.</td>
</tr>
</tbody>
</table>

**Table 1: Survey A (expectations) and Survey B (experiences) questions.**

**Expanding student surveys**

Service teaching working party members and numerous HODs and other academics at physics departments across Australia were pivotal in expanding the reach of the expectations/experience surveys. We surveyed students from 35 subjects taught to non-physics majors in 22 Australian universities spanning the Australian Capital Territory, New South Wales, Queensland, South Australia, Victoria and Western Australia. Over 7500 completed surveys were returned for analysis. The surveys were carried out at the beginning and end of the autumn
semester 2008. There was good representation from GO8, ATN, as well as rural and regional universities. Table 2 contains the participating universities.

<table>
<thead>
<tr>
<th>Curtin University of Technology</th>
<th>The University of New South Wales</th>
</tr>
</thead>
<tbody>
<tr>
<td>CQ University</td>
<td>The University of Newcastle</td>
</tr>
<tr>
<td>Edith Cowan University</td>
<td>The University of Queensland</td>
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<tr>
<td>Flinders University</td>
<td>The University of Sydney</td>
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<tr>
<td>La Trobe University</td>
<td>The University of Western Australia</td>
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<tr>
<td>Murdoch University</td>
<td>University of New England</td>
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<tr>
<td>Queensland University of Technology</td>
<td>University of South Australia</td>
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<tr>
<td>RMIT University</td>
<td>University of Technology, Sydney</td>
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<tr>
<td>Swinburne University of Technology</td>
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<td>UNSW@ADFA</td>
</tr>
<tr>
<td>The University of Adelaide</td>
<td>Victoria University</td>
</tr>
</tbody>
</table>

Table 2: Universities that participated in the national expectations/experiences surveys

Survey A was administered to students in week 1 or 2 of autumn semester 2008. Survey B was administered at the end of the semester but before the formal examination period. The contact person at each physics department was responsible for coordinating the appropriate time and place for administering the survey, collecting the completed surveys and returning them to the project officer for analysis. The option of keeping copies of the completed surveys (for personal analysis) was available to each department; the project team, however, was responsible for analysing the complete data set. Once this analysis was completed, departments were sent a copy of their individual results. The overall results could be made available to individuals upon request, with any information leading to the identification of departments or individuals removed.

Anticipating the large number of data to be collected, the surveys were prepared in computer scan-able format to facilitate the data management process. Once all the Survey A responses were collected they were sent to the Planning and Quality Unit (PQU) at UTS for scanning. The same occurred when the Survey B responses were collected. PQU was responsible for scanning 4414 Survey A and 3109 Survey B responses and embedding the data in Excel spreadsheets.

All the subsequent data analysis was carried out in these spreadsheets by the project officer and the working party leader. The analysis was chiefly statistical. The main component involved averaging the quantitative, multiple-choice questions, resulting in mean values for individual questions, both for the overall data set and for each of the 35 subjects. An overall performance gauge for each subject was also developed, referred to as the index of change (IOC). The purpose of the IOC was to create an indicator representative of the change occurring between student expectations and experiences for each subject. The IOC is the mean of all the questions’ (experience – expectation) scores and an individual value was calculated for each subject.
Undergraduate experimentation

Preamble
The purpose of the undergraduate experimentation strand of the project was to investigate effective undergraduate laboratory learning environments and engage the community in developing sustainable research-based teaching practices. We aimed to disseminate the findings through workshops involving physics academics, contact with discipline leaders (such as HODs and the ACDS), a website and papers presented at national conferences.

A recent trend – the erosion of time spent by undergraduates doing laboratory work – is worrying to the majority of physics educators, who consider it an important component of the undergraduate physics degree. These reductions have occurred due to the decrease in resources to maintain undergraduate laboratory programs and the increasing use of computer simulations to replace hands-on laboratory activities. To counterbalance this we set out to assist physics departments in Australian universities to maintain and improve their laboratory programs by assisting in sharing of resources and promoting communication between physics educators (particularly those with an interest in laboratory work) and by developing tools to evaluate laboratory experiments.

Strategies: workshops and the ACELL approach
ACELL workshop
In the first project workshop, held in September 2007, as part of the UniServe Science education conference, participants discussed their current laboratory teaching practices. There was also a discussion about how these practices could be improved, and what support the project team could provide for this. At this initial workshop there were various presentations made, including one by the Advancing Chemistry by Enhancing Learning in the Laboratory (ACELL) project officer, Justin Read. At this workshop the project participants expressed interest in pursuing the ACELL experiment evaluation process for first year undergraduate physics experiments. This process uses research-based evaluation procedures to assess the educational value of experiments. In doing so it encourages the proponent of an experiment to become familiar with current education research and practice, and to think critically about their own teaching practices, with respect to the experiment which they are proposing. Details of the ACELL evaluation process, including completion of substantial educational templates, workshop and in situ testing, can be found on the ACELL website: acell.chem.usyd.edu.au/.

An ACELL-style workshop with over 50 participants was held at UTS in November 2007. Eight experiments spanning a range of topics were promoted by academics from six universities. The eight academics completed the ACELL education templates for their experiments, containing the information required under the ACELL process. The experiments were then undertaken by groups of “students”. The “students” consisted of a mixture of academics, including lecturers and some deans of science from 19 universities, as well as undergraduate students from several universities.

At the completion of the experiments the “students” evaluated both the experiments and the educational templates provided with the experiments. Further feedback on the experiments and the process was provided in discussion sessions at the end of the day. Much useful feedback was provided by the “students”, and it also provided an opportunity for the academic who acted as
demonstrator to better explain the educational context of the experiment. Following the workshop, a survey was sent to all participants asking for their views on the day.

Overall the responses to the ACELL methodology were very positive, with some concerns about timeliness and workload [8]. After evaluation of the eight experiments was carried out by Justin Read, three experiments were earmarked for the next stage of the ACELL process. This involved having the experiments tested in situ and being included amongst the refereed experiments shown on the ACELL website, with a view to publishing the experiments in an appropriate journal.

Higher year experiment repository
Workshops in June 2008 (at Monash University) and September 2008 (at Sydney University) provided further opportunities for the physics community to discuss the possibility of a continuing involvement in the ACELL process and the implications involved in taking this path. Additionally, the June 2008 workshop was a platform for showcasing and addressing issues arising in higher year laboratories. One of the main issues that arose out of these discussions was the pressing need for a readily accessible list of second and third year experiments in current use across Australian physics departments. A recommendation was made that, as part of the project, a webpage be developed containing an extensive listing of the experiments available, with a short description attached and, most importantly, a contact name attached. This repository has since been developed (as part of the website resulting from the project) and it is hoped that its growth and upkeep can be maintained.

Graduates in the workforce
Preamble
The purpose of the graduates in the workforce strand of the project was to identify graduate destinations and employer expectations, to explore the employment opportunities available to Australian physics graduates and to 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.

Strategies: graduate and employer surveys
Survey development
During 2007, two related surveys were developed to explore the diverse employment opportunities available to Australian physics graduates as stated in the preamble.

A graduate survey was developed that significantly expanded on questions asked of graduates in interviews in the 2004/5 AUTC Physics Project [1]. 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 its trial, with the result that the employer questions closely complemented those of the graduate survey.

Both surveys were finalised at the beginning of 2008 and were placed online at SurveyMonkey, a professional survey hosting website, in February. 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.

**Graduate and employer surveys**
The graduate survey (available on the project website [4], and as an appendix to this report) was extensive and consisted of over 40 questions spread over five 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 take part 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, learn more about the project and hopefully complete the survey.

The employer survey (also available on the project website [4], and as an appendix to this report) 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 take part in a further interview to probe some of the questions more fully.

**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, i.e. 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, but 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. The 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 lack of ready access to alumni lists is an interesting observation to emerge from this study.

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 2008. 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 did not place any age limit on who could complete the survey. The responses from older graduates are valuable but were 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 wide range in size and location: The University of Adelaide, Central Queensland University, Murdoch University, The University of New South Wales, RMIT University, The University of Sydney and University of Technology, Sydney.

Data management and analysis
On the whole the analysis was a straightforward statistical analysis of quantitative data produced by many of the questions. Among the statistical data compiled were:

- mean and median age of respondents;
- gender ratio;
- why graduates chose to do physics at university;
- type of undergraduate and postgraduate degrees;
- university at which degrees were awarded;
- most helpful features of physics education;
degree to which graduate attributes were developed in physics education;
first job upon graduation and current job (by sector); and
usefulness of physics education in the workplace.

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, for example female graduates, graduates with a postgraduate degree in physics, and graduates with no postgraduate qualifications in any field.

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 was sent by email in July. Approximately 45 respondents who had indicated they were willing to take part in a further interview were contacted in this manner. Additionally, graduates were asked to provide a short profile of their career to date and the part a physics education has played.

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 profiles provided by graduates underwent some editing and format standardisation and, after approval was gained from each graduate, 13 were placed on the project website.

Employer survey
The early response to the employer survey was somewhat disappointing, 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 further 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 to the value of a physics education.
Stakeholders

Key stakeholders and how they were involved in, or engaged with, the initiative

Undergraduate students
Throughout the course of the project, and in each of the three separate strands, we have engaged with a large number of undergraduate students. The findings arising from each strand’s studies have the potential to greatly benefit undergraduates in future years.

Service Teaching – First year students undertaking physics predominantly, but not exclusively, as a service subject were surveyed at 22 universities. The feedback obtained from approximately 4000 students has been utilised by the project team, individual lecturers and course co-ordinators in order to identify and address areas of strength and weakness in the teaching and learning of these subjects.

Undergraduate Experimentation – Undergraduates have been involved in two separate stages of the ACELL process of evaluating physics experiments. In the first instance, undergraduate students from various Sydney-based universities, as well as from La Trobe University and The University of Adelaide took part in a workshop to test a number of experiments put forward by physics academics. Once the ‘scores’ from this workshop were analysed, three experiments were chosen as suitable for the next stage of evaluation. The ensuing in situ evaluation involved surveying laboratory classes in three separate departments, where feedback was obtained from approximately 200 first year students. The undergraduate feedback has allowed the academic responsible for each experiment to identify and address issues associated with the experiment.

Graduates in the Workforce – Due to the nature of the study, there has been little or no direct involvement with undergraduates.

University physics academics and researchers
A significant number of physics academics and researchers from across Australia have engaged with the project. Aside from the nearly 40 working party members directly involved, many other academics have taken the available opportunities to contribute to, and gain from, the findings of each strand’s studies. Dissemination of the project’s findings has taken place in a systematic manner, with all physics departments kept up-to-date through regular email updates and online discussions. Additionally the five workshops organised by the project team were well attended, with good representation from across Australian physics departments. Nationwide exposure was achieved by featured presentations by the project team at the UniServe Science conference in 2007 and 2008 and the AIP conference at the end of 2008.

Service Teaching – The involvement of academics in workshops and by email was key to identifying indicators of good practice which then became the foundation for developing the expectations/experiences surveys. The administration of the various surveys was primarily made possible by the assistance of academics at 22 physics departments. This included the cooperation and assistance of many non-working party members, including full-time and part-time teaching staff as well as program co-ordinators. Communication was two-way: the academics received supplementary subject feedback and were generally keenly interested in the findings of the service teaching surveys, both at a local and national level.
Undergraduate Experimentation – Academics have been heavily involved in the various phases of this part of the project. The trialling of the ACELL process in the physics setting gave eight academics the opportunity to present their first year experiments for extensive evaluation and feedback. The process provided these academics with a good deal of awareness about the strengths and weaknesses of their particular experiments and with the knowledge of where changes can (if necessary) be made. The other academics, those involved in the evaluation process but not putting forward an experiment of their own, were able to take away with them a better understanding of what might work best in their own laboratory programs. The evaluation also gave academics a taste of the student perspective, since they were asked to approach the experiments as a student might and also work in groups with current students. After the initial evaluation, three academics were further engaged with the project by having their experiments evaluated by students in situ and two academics have adopted experiments they experienced at the workshop in their own institutions. All academics who attended the workshop emerged with a raised awareness of the ACELL process.

The other outcome of this strand, the setting up of a repository of second and third year experiments on the webpage, has so far involved the active engagement of academics from 16 physics departments. These academics (often several from the one department) have been responsible for compiling all the information that has been collected and placed in the repository, and this information has been viewed by other academics looking for ideas for experiments.

Graduates in the Workforce – Academics from 15 physics departments made significant contributions to the administering of our graduate survey, via their efforts in identifying, locating and contacting past graduates and (by extension) their employers. The findings of the graduate/employer surveys, and the implications for undergraduate teaching and learning, have hopefully been of significant benefit to all physics departments. Additionally it has reinforced the need for (as well as the difficulties involved in) maintaining/updating alumni lists and the value of up-to-date and varied graduate profiles as a marketing tool.

University science academics
Throughout the course of the project we have forged and maintained strong links with two groups within the science discipline: The Australian Council of Deans of Science (ACDS) and a group of chemistry academics who have developed the Advancing Chemistry Education through Laboratory Learning (ACELL) approach for the evaluation of individual experiments in the undergraduate laboratory. The links between our project and these two groups are detailed in the Linkages section. These links are continuing.

Heads of physics departments and groups
Heads of physics departments were actively engaged in the project through invitations to nominate academics to be responsible for the successful implementation of the various surveys. Findings of the surveys were fed back to the HODs and the academics involved. HODs were informed of the general progress of the project (via regular emails). Before each event (i.e. workshops) HODs were informed of the proposed event and invited to send a participant from their department. After the event the HODs were sent a one-page report about the event and thanked for their participation. One result of this procedure was that two universities (La Trobe University and The University of Adelaide) funded several undergraduates, together with academics, to travel to Sydney to participate in a day-long workshop. Another result was that the participating
academics were acknowledged and recognised for their participation, raising the profile of teaching and learning activities within their department.

A formal presentation was made by the project leaders to the annual meeting of Australian physics HODs at the 2008 AIP Congress, thanking them for their department’s participation and assistance, outlining the major outcomes of the project and seeking their feedback on the project’s relevance and possible future directions.

**Client departments / disciplines for service teaching**

It was our original intention to directly canvass the views of client department representatives. However the expansion of other aspects of the service teaching strand (particularly the efforts made to capture the student voice) meant that this was not possible within the time frame and resources available. We remark that any future project focusing on physics service teaching should give the inclusion of client department views high priority.

**Physics graduates**

In the graduates in the workforce strand the graduate survey attracted responses from 171 graduates with physics-related degrees, both undergraduate and postgraduate representing 22 Australian universities. These included 108 respondents who graduated after 1990. The extensive survey not only provided much important data for the project but also gave graduates an opportunity to reflect on their physics education and how it prepared them for entry into the workforce. Fifteen graduates responded to a further set of questions probing their earlier responses, and provided profiles for showcasing on the project website.

**Employers**

In the graduates in the workforce strand an employer survey was developed in conjunction with, and partly analogous to, the graduate survey. The graduate survey was completed by over 100 physics graduates currently in the workforce. In order to identify employers of physicists and have them complete the survey, the graduates who completed the survey were asked to provide the project team with their employer contact details and/or approach them directly. For a number of reasons (reluctance on the part of graduates to bother their employer, reluctance on the part of employers due to time and effort required, etc), only supervisors from the following employers completed the survey:

- Australian Radiation Services Pty. Ltd.
- Canon Information Systems Research Australia Pty. Ltd.
- Dow Corning Corporation
- Fluorosolar Systems Ltd.
- Fuji Xerox Australia Pty. Ltd.
- Oakhill College
- Phonak Australia Pty. Ltd.
- Queensland Alumina Ltd.
- Warrnambool College

Although the small amount of data collected from employers lends itself less to statistical analysis than hoped, it did corroborate views from employers (gathered in the 2004/5 AUTC project) about the extent to which certain skills are developed in the physics degree. It also provided employers with a forum in which to consider the qualities their employees, as physics graduates, have brought to the job.
The Australian Institute of Physics (AIP)
We have maintained close contact with the AIP, updating them on the state of the project, in particular our findings involving graduate destinations and employment, a shared interest. Currently we are engaged in discussions with the current and future presidents of the AIP regarding the hosting of the project website on the AIP server. The AIP website is a natural home for the project website, as it is a site that is frequently visited by physics professionals, future physics graduates and the physics academic community. Also, the AIP has the resources to maintain and update the website to the benefit of the whole physics community.
Major outcomes from the project

**Service teaching**

As expressed in the original project proposal, the intended deliverables from the service teaching working party were:

1) A project website containing resource materials for innovative and successful curricula and practice in strategically selected service areas.

The website for this project has pages devoted to the service teaching strand [1]. These pages include resource materials in the form of surveys, which were developed to allow examination of subjects designed for non-physics majors. A selection of results from these surveys, carried out across 22 universities during the autumn semester 2008, is included on these webpages.

2) Workshops and networking meetings for examining and disseminating good practice in service teaching.

National workshops were held in which:

a) Indicators of good practice were identified, collated and examined. This workshop took place on the Physics Discipline Day at the UniServe Science conference, 26 September 2007.

b) Examples of good practice were promoted and effective methods of disseminating and embedding good practice within physics departments were explored. This workshop took place on the Physics Discipline Day at the UniServe Science conference, 1 October 2008.

c) Dissemination of the findings of the service teaching strand occurred as part of a workshop that promoted the findings of all strands of the project. This workshop took place at the Australian Institute of Physics Congress, 4 December 2008.

3) Document features that define quality service teaching within particular local contexts.

Through the expectations/experiences surveys, several subjects were identified as being particularly successful at matching high level student expectations with equally high quality student experiences. The co-ordinators of those subjects were invited to make a presentation at a national conference (UniServe, 2008), describing their subject and the factors that they believe contributed to the high quality student experiences as related by the students themselves. They were also asked (and agreed) to contribute an accompanying short piece for the project website, containing in particular:

a) a brief description of the subject (including details of content, teaching methods and assessment);

b) a reflection on the questions relating to student perceptions of the value of the subject and links to the major, and why student responses were so positive;

c) aspects of the subject that are especially innovative or noteworthy;

d) broad demographic details of students; and

e) details of the typical responses to their own internal subject feedback surveys.
A short piece authored by each of the coordinators can be found on the project website and may also be found in Appendix 3.

**Unanticipated significant outcomes**

As a result of moving towards an evidence-based consideration of good practice in physics service teaching in Australia, it was necessary to diminish the influence self-reporting of good practice by academics, in favour of more independent measures. This led to the following unanticipated outcomes:

- the proposing of models of subjects taught to non-physics majors with a view to establishing whether the model and indicators of good practice are related; and
- surveying students nationally about their perceptions of physics service subjects (for example, how well they believe the service subject links to their major area of study).

The scale of the response to the invitation to be involved in such a national survey was overwhelming, though welcome (with over 7500 surveys returned for analysis). This required more resources to be allocated to this task than originally intended. The extra resources allocated were worthwhile as there was much benefit to be had, as examples:

- **locally** – academics in each university (to which the analysed surveys were returned) were able to examine the impact that their service subject has on students; and
- **nationally** – data that were nationally representative allowed the identification of issues of national importance.

Owing to the large numbers of expectations/experiences surveys received, and the richness of information contained in the surveys, the resources allocated to the task of administering, collecting, collating and analysing the data, especially with respect to project officer time, were greater than originally planned. This ‘human resources’- intensive activity was also partially responsible for the request to delay the reporting date for the project to March 2009.

**Implications for the sector resulting from the project**

The review of physics service teaching in Australia, including teaching materials, indicators of good practice identified by academics, student surveys and feedback from academics, supports the view that the basic tenets of good practice in teaching also apply to physics service teaching. Evidence has emerged that non-physics majors enter physics subjects with high expectations with regard to the value of the subject, its links to their major and laboratory work, but only a relatively small fraction of subjects (in this study) can report that the students’ experiences matched their expectations.

Those staff whose subjects were responded to positively were in no doubt that the emphasis on relevance that they embedded into the subject was a key factor in positive student responses, and this aligns closely with the indicators of good practice in teaching to non-physics majors, as articulated early in the project by physics academics. The message is that with relevance comes engagement, and those subjects that have paid particular attention to that have been rewarded with positive student feedback. While *physics-for-physics-sake* may satisfy academics, without a serious intent to bring in applications that have meaning to
students, physics academics risk their subject being regarded by non-physics majors as peripheral at best and irrelevant at worst.

Laboratory work for non-physics majors is a major issue, and this comment applies to those subjects that otherwise scored highly in the responses of students in the experience surveys, as well as for those subjects that scored less well. The issue of laboratory work for non-physics majors intersects with the undergraduate experimentation strand of this project. This is an area which requires further work, as laboratory work has the potential, apparently not being realised, to bring the physics alive for students not intending to major in physics. Laboratory work brings many other benefits, such as fostering the development of effective oral and written communication, working productively in groups, and devising and testing creative solutions to novel situations.

Owing to the role it plays in preparing a large fraction of the next generation of physics teachers, its potential influence on student attrition and the financial security it brings to physics departments, physics service teaching deserves to remain high on the agenda for the tertiary physics education community in Australia.

**Undergraduate experimentation**

As expressed in the original project proposal, the intended deliverables for this strand of the project were:

1) A project webpage containing effective and efficient laboratory and project programs, including ‘effective/motivating’ experiments.

2) Workshops based around ‘effective/motivating’ experiments to engage the community in sharing materials.

3) Document features of effective and efficient experimental programs within particular local contexts.

Owing to the interaction with the ACELL group, an emphasis of this strand (which was not an original intended outcome of this project) has been to engage intensely (and practically) with the ACELL methodology, with a view to advising the physics community on its applicability to the evaluation of physics experiments. This led to less emphasis on the intended outcomes expressed in the original project proposal, such as populating a website ‘with effective and efficient laboratory and project programs’. However, the establishment of the repository of second and third year experiments does go some way to meeting this goal. While these experiments have not been tested, the contact details provided allow an interested person to follow up with someone knowledgeable about the experiment.

Since the November 2007 workshop, there have been three important outcomes of the trial of the ACELL process for physics experiments. First, at least two of the experiments presented at the workshop have since been adopted by other institutions. Second, three of the academics who presented experiments are pursuing the ACELL process and are working with the ACELL project team to have their experiments tested in situ and included amongst the refereed experiments shown on the ACELL website, with a view to publishing their experiments in a peer-reviewed journal. Third, the physics education community is collaborating with the ACELL project team to expand the project to include
physics and biology, and become ASELL (Advancing Science by Enhancing Learning in the Laboratory).

In addition to these concrete outcomes, the interaction between this project and the ACELL project has led many of the participants at the workshops to reflect more critically on the undergraduate laboratory experience at their institutions. The ACELL evaluation process, which is based on education research, can be applied not only to evaluating experiments but also to designing them. This is important, as many of the workshop attendees and working party members are academics with roles and responsibilities in course design. This thrust to thinking critically about our lab programs has been further stimulated by the interaction between this project and the project currently being undertaken by the ACDS under the leadership of Prof. Sue Thomas and Prof. John Rice, as described in the next section.

**Unanticipated but significant outcomes**

A further workshop held in June 2008 at Monash University identified the need for greater sharing of resources for higher year physics laboratories. This has led to the production of a second and third year lab repository on the project website. This repository has so far received contributions from 16 different universities. Several others responded to requests but said that they did not teach physics at higher levels and hence were unable to contribute. At present we have collected data concerning 218 second year and 173 third year experiments. The topic areas covered include: astronomy, atomic physics, electromagnetism, electronics, fluids, mechanics, nuclear physics, waves, optics and photonics, quantum physics, condensed matter physics and thermodynamics. Each listing includes a short description of the experiment and a contact person’s details. This person has agreed to be contactable by people wanting to know more about that experiment, and potentially visit the institution to observe it *in situ*, which is particularly useful for putting the experiment in context.

The repository can be accessed through the undergraduate experimentation pages of the project website [4]. It does not include exhaustive information, in the style of ACELL experiment listings, and this is intentional. Few academics have the time or inclination to complete such extremely detailed templates for a large number of experiments. Hence the template used requires only brief details. This makes the process very easy for those contributing and has allowed the collection of information for a large number of experiments. It is anticipated that this resource will continue to grow. While this is not the form of resource originally envisaged, it does provide academics with a database of ideas for experiments and will hopefully encourage greater sharing of resources and collaboration between academics working to develop higher year laboratory programs.

A further unanticipated and valued outcome of the project has been the interaction with the ACDS project *Reconceptualising Tertiary Science Education for the 21st Century*. Various project members including Kate Wilson and Les Kirkup have had discussions with the ACDS project team and John Rice has attended two physics workshops and described the findings of his project. A key area of common ground is the recognition of the need to articulate the purpose of laboratory programs as distinct from individual experiments. Professor Rice’s presentations resulted in a great deal of discussion on both occasions, and have stimulated many participants to review their demonstrator training practices, their own views of the importance of laboratory programs, and how the goals of such programs are communicated to
students. This is a very important issue and not one that could be addressed in the current project, not least because it was largely raised towards the end of the project. However, it is hoped that a future discipline-based physics project will be able to address these issues.

The start of the project was considerably delayed owing to protracted contract negotiations. In addition, the working party leader, Kate Wilson, was on maternity leave for the first six months of 2008, which had an impact on the project timeline for the undergraduate experimentation strand. The changing of project officers in the middle of the project made some aspects of the project that had originally been planned, such as more site visits to investigate laboratory programs, extremely difficult.

**The implications for the sector resulting from the project**

The testing of the ACELL experiment evaluation tool in a physics setting has provided a useful research-based tool for evaluating undergraduate physics experiments. Further work needs to be done to modify this tool if it is to be more broadly applicable. In its current form it cannot be used to evaluate more open-ended activities such as projects or extended experiments which take more than a few hours. In addition, the ACDS project has highlighted the need to consider laboratory programs more holistically, and no means of evaluating entire programs is currently available. Nonetheless, the ACELL (or future ASELL) process can be of great value to physics educators in designing and evaluating their undergraduate experiments. The existence of such a process and its uptake will stimulate not only those directly using it, but their colleagues also, to think more critically about the experiments undertaken in undergraduate teaching laboratories. The expansion of the ACELL project to include physics will need support both financially and in terms of the participation of the physics community.

The interaction with the ACDS project has identified the need for a more holistic or programmatic approach to undergraduate teaching laboratories. In particular, the need for casual teaching staff to be informed of the aims of laboratory programs and to be included in their development, and the effective communication of these aims to students. There is evidently a need for improved design of laboratory courses and improved professional development and support for teaching staff. The identification of this need has led to an expression of interest, for a project to address these issues being submitted to ALTC. In addition, there is further interaction, particularly through workshops, planned between the ACDS group and the current physics group when the recommendations from the ACDS project are announced.

The availability of the resources for higher year labs in the online repository will assist in the development of higher year laboratory programs. It will also encourage discussion of laboratory classes at higher year levels. However, for this repository to remain useful it will need to be kept up to date, in particular with respect to contact names. This will require the repository to be ‘adopted’, either by an ongoing group at an institution, or by an organisation such as the Australian Institute of Physics. This latter option is currently under discussion with the president of the AIP.

**Graduates in the workforce**

As expressed in the original project proposal, the intended deliverables for this stand were:

1) *Profiles of physics graduates in the workforce, and what employers say about them, to be produced on flyers and websites (both project website and institutional websites).*
One of the outcomes of the graduate survey, and specifically the follow-up questions, was the compiling of 13 physics graduate profiles. These profiles can be found on the project website and they have also been made available to the corresponding physics departments for possible inclusion on their individual pages (some of them already are).

2) Document strengths of current physics education as well as the challenges faced in preparing students for actual destinations in the workforce, with feedback to departments, instructional designers, employers and student advisors.

The vast amount of data collected from the online graduate and employer surveys has been extensively analysed and the strengths and challenges documented in a substantive report (see Appendix 4). A hardcopy of this report will be sent to all Australian physics departments, the AIP and all other relevant bodies. It will also be downloadable from the project website.

One non-refereed and one refereed conference paper emerged for this strand of the project. The first paper considered the question: “Why do Physics? Where does it really lead?” The second paper reported on the physics graduates and employers sampled by the surveys and primarily on one aspect of their responses: the graduate attributes developed during their university physics education.

Unanticipated but significant outcomes
Owing to the large number of graduate survey responses received, the project team has been able to compile an extensive list of job destinations for physicists upon entering the workforce. These positions and the names of the employers are showcased on the project website alongside the graduate profiles. It is hoped that this resource will be utilised by physics educators to demonstrate to students the extensive selection of careers that a physics education can lead to.

The difficulties involved in obtaining lists of alumni from the majority of Australian physics departments has emphasised the poor knowledge most departments have of their own graduates. This should be a serious concern for departments if they expect to be responsive to the needs of their graduates.

Although the alumni from many universities were difficult to find, the main impediment to obtaining a well rounded picture of the employment situation in relation to physics graduates has been the difficulties involved in identifying and acquiring information from a large selection of employers.

The implications for the sector resulting from the project
The similarity of graduate responses reflects considerable uniformity in the university experience of physics for most graduates across the country. In contrast, the diversity of employer responses in the current survey seems to reflect the diversity of physics employment.

Overwhelmingly, graduates refer to the range of skills they acquire, rather than any specific knowledge, as the primary benefits of a physics education. It not surprising then that the laboratory component is nominated as the most helpful component of their course. This is especially important given the emphasis on laboratory issues in the other strands of this project.
Despite the emphasis on technical skills physics graduates experienced in their courses, it is worrying that employers do not believe these translate into skills in research methodology or project planning. This suggests that students require more experience in working independently and planning their own activities.

Both the graduate and employer surveys endorse the prevailing view that there are considerable gaps between attributes students gain from their undergraduate science degree and what they see as important to their current employment. The perceived lack of skills related to communication is a persistent theme to emerge from this survey.

Almost all the employers believe that graduates need various attributes to be better developed at university than they are at present. However, they acknowledge that attributes should also be further developed in the workplace.

While they recognise the skills that physics graduates do bring to their jobs, the employers did not see much difference in the ability to learn and adapt between graduates in physics and other disciplines. Few said they would seek to employ a physicist in preference to a graduate from other disciplines, although several did suggest that physics graduates remain distinguishable in the workplace from other graduates, displaying a broader perspective and an ability to think outside the box.

Finally, an interesting and perhaps disturbing result of the survey is the lack of interest in ethical and social issues amongst graduates. Whilst all graduates report that it is given scant consideration in their degrees, few believe it requires more emphasis.
The state of the discipline

What is working well and should be capitalised upon?

Through projects funded by the AUTC, Carrick and the ALTC, between 2004 and 2008, physics academic staff have been drawn together to explore and act in a practical way on issues of moment to the tertiary physics sector. The core group of academics driving the initiatives have benefitted greatly from the support provided by ALTC grants. The enthusiasm of such staff and the ability to uplift university physics education should be capitalised on by supporting discipline-based initiatives. These initiatives provide national benefit in terms of improved course design, recognition for academic involvement in teaching and learning developments and identifying and acting on themes of national significance. In particular, university physics education has a history of pioneers in discipline based education research, networking and sharing of ideas which, in the current race to balance research and teaching, can be lost. More avenues to support the networking and sharing of ideas should be pursued. One obvious example, used extensively and effectively in this project, is the use of workshops. They are a means of building and maintaining networks and collaborations, and have a motivating effect on academics who may not have a network of colleagues with a strong interest in teaching and learning at their home institution.

Physics research in Australia is world class and highly successful. Currently there is an inadequate supply of PhD candidates flowing on from undergraduate studies to drive the research engine. We need to capitalise on the strength in physics research and to bring the supply level to what Australia needs and to maintain that level. To this end efforts need to be made to improve physics majors programs – an area not explicitly funded to date.

Physics is a vital enabling discipline driving the Australian economy as evidenced by two facts. First, a vast number of degree programs and majors ranging from forensic science to zoology require physics as a service subject for the underpinning of their later studies. Second, physics graduates are employed in a diverse range of occupations. Furthermore physics is viewed as particularly difficult, so careful planning of the curriculum is required to motivate students, which takes in to account the needs of a wide range of stakeholders and not just those going into careers in physics. Physics not only requires but also develops an extensive toolkit needed by students. To capitalise on the capacities and capabilities recognised as adding value to the workforce, projects into motivating and engaging students need to be explored, for both service teaching and mainstream physics. We note that there are forecasts of shortages of science and engineering graduates in the near future, with physics in the forefront.

Where are the gaps?

1. Teaching in laboratories

Teaching and learning in laboratories is an issue across the sciences. There has been a series of projects devoted to this issue and there is little doubt that more needs to be done. The ACDS project has explored whether laboratory work is necessary. There is still work to be done to clarify which of the graduate capabilities that laboratories are able to inspire are vital for science graduates who do not pursue a career in science. In physics laboratories, we need to address:

1. How individual experiments can be better designed and implemented and to build up a database of such experiments (as in ACELL);
2. How laboratory programs can be improved for a course or for a degree program; and
3. Tutor and casual demonstrator professional development issues.

2. Innovative learning and teaching spaces
Innovative teaching and learning spaces for physics education are being used at institutions such as MIT and Harvard. Across Australia some attempts have been made to adapt these to our context. Currently some institutions are developing infrastructure in which such innovations could be implemented. While infrastructure funding has been allocated to building these innovative teaching and learning spaces, sufficient resources are not always available for developing/adapting curricula to complement the new spaces. A gap exists between the design of new teaching spaces and demonstrating the teaching and learning benefit. Additional funding is needed for staff time to develop these curricula and to train staff in their implementation.

3. Pre- and in-service physics teacher training
In the arena of teacher pre-service and in-service training, a significant amount needs to be done in physics and the sciences. Primary school teachers need to be comfortable and enthusiastic about mathematics and science. Lower secondary science teachers need to be competent and motivated about the appropriate physics. It is vital that there are sufficient and well trained senior secondary physics teachers. With the advent of the National Curriculum, it seems very timely that special effort be put in to teacher training.

4. Contact with physics graduates
It has become apparent that many physics departments have little knowledge about where their graduates go. This project has filled this gap to a limited extent but it is clear that departments need to keep better contact with their alumni if they expect to be responsive to the needs and experiences of their graduates.

What are the strategies to address the gaps?

1. Teaching in laboratories
Funding is being sought to maintain the momentum gained from projects in recent times. Networks have been established and will be utilised to maximise benefit and up-take through the sector. Furthermore, the sciences are teaming together to work on laboratories via the ACELL project and to address the professional development needs of casual academics who support student learning in the laboratory. Opportunities for engaging Deans and Associate Deans are being explored.

2. Innovative learning and teaching spaces
Established networks are being utilised to identify opportunities for trialling appropriate curricula and funding will be sought for developing material.

3. Pre- and in-service physics teacher training
Isolated efforts are being made across the nation. This matter may be pursued through governmental organisations. The advent of a national curriculum for schools may address some of these issues. In the meantime current networks need to be strengthened and extended.

4. Contact with physics graduates
Some individual physics departments have reasonably good contact with their graduates, however most do not. These departments need to encourage alumni
contacts at the discipline level, where students are likely to identify, rather than the more remote faculty or university levels.

A vision for the discipline

Physics is an essential enabling discipline underpinning modern technology, lifestyle, the national economic strength and one which makes a vital contribution to issues of global significance, such as climate change. The vision for university physics education is to:

- attract students to physics;
- provide the best physics education;
- strengthen physics and multidisciplinary research and development;
- stimulate individuals to engage with the physics around them and utilise physics-based knowledge and skills in their professional careers; and
- imbue the next generation of physicists with the capacity to work towards solving problems that are both applied and fundamental in nature, to the benefit of society nationally and globally.
Forging new directions in physics education in Australian universities

Dissemination strategy

We have adopted a multifaceted and integrated approach to disseminating the findings of this project. The dissemination activities began early in the life cycle of the project. Engaging stakeholders, such as HODs, physics academics, educational developers, students, the Australian Institute of Physics (AIP) and the Australian Council of the Deans of Science (ACDS) has been central to every strand of this project, as it is only through continuous engagement that we can hope to get our message across.

Project website

The project website, accessible at www.physics.usyd.edu.au/super/ALTC/, is the most visible outcome of our project. It is aimed primarily at fellow academics in tertiary physics education and clarifies the background to the study, the methodologies adopted, the findings and catalogues the various survey instruments. It also serves as a repository for the refereed papers we have published and workshops we have conducted as the project has progressed. The figure below shows the website’s homepage. From the homepage you can navigate to pages that deal with each of the three strands of the project.

Workshops

Workshops have been an excellent means of disseminating the findings of the project, evaluating the project’s progress and refining its directions. Over the period of the project there have been five national workshops. Three of the
workshops have taken place before or during national conferences, thus benefitting from the large attendance. The workshops were attended by academics from across Australia. Details can be found in Table 3 below (workshop reports can be found on the project website).

<table>
<thead>
<tr>
<th>Date</th>
<th>Venue</th>
<th>Workshop name</th>
<th>Attended by</th>
<th>Topics considered</th>
</tr>
</thead>
<tbody>
<tr>
<td>26/9/07</td>
<td>The University of Sydney</td>
<td>Forging New Directions</td>
<td>36 delegates from 17 institutions</td>
<td>All three strands of the project</td>
</tr>
<tr>
<td>29/11/07</td>
<td>University of Technology, Sydney</td>
<td>Assessing Undergraduate Physics Experiments Using the ACELL Methodology</td>
<td>60 delegates from 19 institutions (including Chemistry academics as well as some Deans and Associate Deans Teaching and Learning)</td>
<td>Undergraduate experimentation strand</td>
</tr>
<tr>
<td>6/6/08</td>
<td>Monash University</td>
<td>Goals and Possibilities for the Higher Year Physics Laboratory</td>
<td>18 delegates from 9 institutions</td>
<td>Undergraduate experimentation strand</td>
</tr>
<tr>
<td>1/10/08</td>
<td>The University of Sydney</td>
<td>Emerging Opportunities in Physics Education</td>
<td>34 delegates from 12 institutions</td>
<td>All three strands of the project</td>
</tr>
<tr>
<td>4/12/08</td>
<td>The University of Adelaide</td>
<td>ALTC Physics Workshop</td>
<td>30 delegates from 10 institutions</td>
<td>All three strands of the project</td>
</tr>
</tbody>
</table>

Table 3: Details of workshops organised by project.

Presentations at conferences
We have presented findings at national conferences in Sydney and in Adelaide. The presentations in Sydney took place at the UniServe conference in 2007 and 2008. In addition to the physics community the UniServe conference attracts delegates from a wide range of science disciplines. The conference in Adelaide was attended primarily by physicists from Australia and overseas. Pleasingly, as this was the AIP biennial national conference, those attending the education presentations were not solely from the physics education community and included non-teaching academics and graduate students.

In addition to formal presentations (which also appeared as publications and are described in the next section) we were also given the opportunity to present the project’s findings at meetings of the Heads of Physics Departments. These meetings took place at the 2008 AIP conference to discuss matters of moment. At the main meeting we made a presentation to 18 HODs (or their representatives), providing a description of the project, its aims and outcomes, and giving them a thorough overview of the project website. At a second meeting we met with five HODs.

Publications
There are seven publications that have emerged directly from the work described in this report. Six of the seven publications have been refereed and satisfy the E1 category of publications as defined by The Department of Innovation,
Industry, Science and Research (DIISR). The publication titles, which can be accessed as downloadable pdfs on the project website, are as follows:

- **Teaching physics to non-physics majors: models extant in Australian universities** (UniServe, 2007)
- **Do students’ experiences of a service subject correspond to their expectations?** (UniServe, 2008)
- **ACELL for Physics?** (UniServe, 2008)
- **Why do physics? Where does it really lead?** (UniServe, 2008)
- **One Semester Of Physics: What Difference Does It Make To Non-Physics Majors?** (AIP, 2008)
- **Improving Undergraduate Laboratory Work in Physics: Outcomes of the ‘Forging New Directions in Physics Education in Australian Universities’ Project** (AIP, 2008)
- **Physics Graduates in the Workforce: Does Physics Education Help?** (AIP, 2008)

**Invited presentations**

Some of the findings of the project have been presented to academics within and outside the physics community. As an example, ‘Why service teaching is the most important teaching you’ll ever do’ (which related some of the findings from the service teaching strand of this project) was presented to the Faculty of Health Sciences at the University of Sydney on February 3rd 2009. An invitation has been received from ANU to present some of the findings of the service teaching strand of the project. That presentation will occur on March 27th 2009.

**Future dissemination opportunities**

We believe there is much in this project that is of value both to the physics community and to the wider tertiary education community. We are alert to opportunities both within our discipline and outside of it. To date we have four invitations to present our work in 2009 at Flinders University, Griffith University, La Trobe University and RMIT.
Linkages

As a consequence of this project we have forged strong links with two important groups: the Australian Council of Deans of Science (ACDS) and a group of chemistry academics who have developed a new and rigorous approach to the evaluation of undergraduate experiments which operates under the banner of Advancing Chemistry Education through Laboratory Learning (ACELL).

There is considerable common ground between the ALTC supported project Reconceptualising Tertiary Science Education for the 21st Century led by Professor Sue Thomas and Professor John Rice and the undergraduate experimentation stream of this project. In particular, the ACDS project examined the role of laboratories in the education of undergraduate students in physics, chemistry and biology and so dovetailed with the more specific consideration given in this project to physics laboratories.

Contact made early in this project with the ACELL group resulted in much common ground being evident between the views of chemists and physicists. A strong commitment emerged to trial the methods pioneered by the ACELL group in order to evaluate physics experiments using the ACELL methodology.

The links between the ACDS and ACELL bore fruit through the national workshop that we organised at UTS in 2007 and was attended by the president of the ACDS and was partially sponsored by the ACDS. The workshop drew together ACELL directors, representatives of the ACDS, physics academics, physics students and working party members from this project in order to trial the ACELL methodology on physics experiments. This whole day workshop was extremely successful and has done much to cement productive relationships between the tertiary physics education community, the ACDS and ACELL.

To further promote dialogue between the ACDS project and our project, we carried out interviews with the then president of the ACDS, Prof. John Rice, during which we considered such issues as “what is the rationale for having laboratory classes in tertiary education?” and “what is really meant by learning science”. The interviews were recorded and transcribed and may be found on the project website. Additionally Prof. Rice accepted our invitation to give a special presentation on the findings of the ACDS project at the October 2008 workshop.

The linkages with the ACELL group have had several tangible outcomes. Currently the ACELL group is looking to expand their methodology to include physics and biology. In pursuit of this, they have submitted an application to the ALTC for funding. As a result of the collaborations that have occurred over the period of this project, one of the leaders of this project (Manjula Sharma) has been invited to be part of the proposed project team, to act in the capacity of leader of the physics component of the Advancing Science by Enhancing Learning in the Laboratory (ASELL) project.

One of the physics experiments that was evaluated in the November 2007 workshop has been further evaluated (by the ACELL group, using their instruments). It has progressed to the stage where a paper has been submitted to an international peer-reviewed journal by Ragbir Bhathal, who attended the workshop and has driven the writing of the paper. The paper is called ‘Educational analysis of a first year engineering physics experiment on standing waves: based on the ACELL approach’. Another experiment, which performed
well in the same workshop, has been trialled with students and it is possible that it too will result in a peer-reviewed paper.

We would like to draw attention to the fact that, as a consequence of this project and the team that was formed, relationships between colleagues within the tertiary physics education community have been strengthened and extended. As a consequence, teams for future work are forming naturally. As an example, Anna Wilson and Kate Wilson submitted an application for funding to the ALTC with the title ‘Enhancing student learning in undergraduate physics laboratories through improved demonstrator practices’, which has recruited academics involved with the current project.
Evaluation

The summative evaluation described in this section is framed in terms of the aims and deliverables of this project, as expressed in the original project proposal. We believe that we have achieved our aims and delivered on our deliverables. In some cases we have been opportunistic and taken the project in directions not originally specified in our proposal – in particular reviewing, trialling and evaluating the ACELL methodology and how it may be used or adapted by the tertiary physics education community in Australia. We are pleased with the level of engagement with the tertiary physics sector that has occurred as a result of this project, the extent and quality of the material we have generated, and the links we have forged within and outside the physics community.

Formative evaluation

Throughout the project there were frequent (often daily) email discussions between the project leaders and the project officer regarding progress. There were also regular discussions between the working party leaders and the project leaders, as well as the project officer. There were regular meetings in Sydney between the project officer and the working party leaders for the service teaching and graduate destinations strand. At each meeting there was a discussion of what had been achieved, what remained to be done, and a to do list drawn up of items to undergo action and by whom. At each meeting the progress on previous items was reviewed and action taken where appropriate. Communications with laboratory project leaders Kate Wilson and David Mills, both based outside Sydney, were largely by email, although early in the project the first project officer did attend several meetings in Canberra. Workshops gave an opportunity for all leaders to meet and review the project.

Five workshops were organised spanning the duration of the project. These workshops were opportunities for delegates, many of whom were working party members, to review progress and to contribute to guiding the project through subsequent phases. Workshops played a major role in reviewing the direction of the project. As an example, at the workshop that took place at Monash University in June 2008 (details can be found on the project website) some delegates expressed concern that evaluating physics experiments using the ACELL methodology was too cumbersome and there was a need to collate information about senior physics experiments currently in use across Australia. More specifically, academics wished to be advised about who had developed the experiments, where they resided and some brief details about the experiment (the topic, level and aim of the experiment). We acted upon that feedback and developed and populated a repository of almost 400 experiments from 16 universities across Australia.

Service teaching

Major consideration of the indicators of good practice in service teaching were proposed, discussed and evaluated at the September 2007 workshop in Sydney. That discussion and evaluation included academics that were members of all the working parties (i.e. not just the service teaching working party), as well as academics not directly involved with any aspect of the project. A vital point learned through the discussions was that a key voice not being heard so far (with respect to factors affecting engagement, for example) was that of the student. This concern was acted upon through the preparation (and trialling) of student
experiences/expectations surveys and represented a major development in the service teaching strand that extended across most of 2008.

Undergraduate experimentation
An initial workshop using the ACELL project approach to evaluating laboratory experiments was run in November 2007 at UTS, in collaboration with ACELL and the ACDS. This workshop was followed up by a survey sent to all participants as well as extensive reflection and discussion by the project group, via email. As foreshadowed in the project application for funding, there have been several meetings with Prof. John Rice (then president of the ACDS) and Paddy O’Toole, the project officer, in which the mutual interests of the ACDS project on ‘Reconceptualising Tertiary Science Education for the 21st Century’ (funded by the ALTC) and our project were explored.

A debrief session was held with Professor Rice after the November 2007 workshop. He indicated that the workshop had convinced him of the applicability of the ACELL methodology to physics (and other science disciplines). His evaluation of the situation was that the physics community would need to conduct more workshops in order to establish the ACELL approach in their discipline. He suggested that they could develop the approach towards some higher level goals for laboratory teaching, by asking questions such as: “how would the experiments [considered at the workshop] assist in concept building?” and “if the experiments were about building technical skills, how could they make those technical skills real/mean something to the student?” The commitment shown by the ACDS to the ACELL process further convinced us of the value of vigorously pursuing, as part of this project, the possibilities that the ACELL methodology offers for enhancing learning in the physics laboratory.

Graduates in the workplace
In 2007 a questionnaire was successfully trialled and initial responses were evaluated leading to modification of the questionnaire. The modified questionnaire was delivered in early 2008.

Formative evaluation/feedback of this strand of the project was provided by the physics HODs at a national meeting of HODs in December 2008 in Adelaide (attended by the project leaders). The feedback was positive with a general call from the meeting (and endorsed by the present and incoming presidents of the AIP) that the AIP offer to host and maintain the website for the current and future benefit of new graduates, physics academics and physics departments across the country.

Summative evaluation
Extend the established network of Australian physics educators
Through project workshops, national conferences, invitations to address Australian physics HODs and visits to physics departments, we have consolidated, strengthened and extended associations between tertiary physics educators. We have done this by working together on this project on matters of mutual benefit and moment to the tertiary physics education community. This project has given academics, working party members, working party leaders and project leaders a strategic focus. The recognition that this work has brought upon involved academics (for example for those academics whose subjects did particularly well in the student expectations/experiences surveys) has had an impact on their standing within their own institutions. The pulling together of academics in the later workshops to review the findings of the project and then
respond to the question “where to next?” resulted in working party members (Anna Wilson and Kate Wilson from ANU) taking leading roles in writing and submitting an application for funding to the ALTC for a project entitled ‘Enhancing student learning in undergraduate physics laboratories through improved demonstrator practices’.

Service teaching
We aim to illuminate what constitutes good practice in physics service teaching. We intend to identify, promote and disseminate good practice, and collate quality resources. We also aim to engage the wider academic and professional communities in order to strengthen traditional partnerships and create new and productive alliances.

In this strand of the project we proposed models by which service subjects could be classified. Through working with the physics community we were able to clarify what was meant by good practice in service teaching. We developed and trialled questionnaires which were intended to explore where good practice was occurring. The questionnaires were administered in 35 service subjects across 22 Australian universities. Through the surveys we obtained a student perspective on what elements/approaches of a service subject led to a positive experience, and which did not. The surveys (which can be found on the project website) are a valuable tool and in the words of one academic administering the surveys: “The A/B surveys greatly assist in understanding the students’ expectations and see how they assess their real experience. This was the only way I’ve learned about areas where we, physics educators, need to modify our vision of service teaching.”

Other feedback from academics administering the surveys has also been positive:

“Based on these data [from the surveys], I’ve modified the teaching strategy in the second semester. As a result, the preliminary student feedback was very positive, and their understanding of the subject and its main concepts has improved significantly compared to the same semester in 2007.”

When asked (as part of a short survey) if the surveys were valuable, one academic responded:

“Of definite value, yes! We have used them to inform our practices of assessment and topic delivery ... I want to exceed the students’ expectations, not just meet them.”

Undergraduate experimentation
We aim to investigate effective undergraduate laboratory learning environments and engage the community in developing sustainable research-based teaching practices.

A methodology for evaluating physics experiments we considered through this strand of the project was that offered by ACELL. Though not part of our original project description, we believed it to be very timely to review the ACELL methodology, then apply it as faithfully as we were able (in that we had the direct involvement of the ACELL directors) to physics experiments. The ACELL workshop that we ran was extremely successful and gave us a first-hand
opportunity to observe the ACELL methodology in action. In addition, the materials created as part of the workshop were shared between academics. An outcome was that experiments showcased at the workshop were taken up and adapted for use by academics in their own institutions.

As a result of the productive relationship formed between the ACELL directors and our project team, one of the project leaders (Manjula Shama) has played a leading role in an EOI submitted to the ALTC, which is designed to progress the ACELL approach into physics and biology.

**Graduates in the workforce**

*We aim to identify graduate destinations and employer expectations and explore the diverse employment opportunities available to physics graduates to determine the suitability of current course content, structures and learning activities.*

In line with the expressed aim in the original project EOI, an online survey was trialled in 2007. We developed the survey further in 2008 and administered it nationally online. The purpose of the survey was to provide a contemporary view of where a physics degree can lead and find out whether physics training was effective and useful to graduates and employers. This aim has been largely met, although a bigger sample of employers in particular would be desirable.

Among the key results was a recognition of skills developed by graduates. While the development of problem solving skills through a physics degree was recognised, other key skills, such as communication and planning skills appeared, in general, to be neglected and responses clearly stated that such skills need more emphasis.

**Evaluation: deliverables**

**Service teaching**

- A project website containing resource materials for innovative and successful curricula and practice in strategically selected service areas.
- Workshops and networking meetings for examining and disseminating good practice in service teaching.
- Document features that define quality service teaching within particular local contexts.

With respect to deliverables for the service teaching strand, we have created webpages which contain the surveys developed to allow users to establish the extent to which student expectations are matched by their experiences. These pages also contain selected results and discussion from these surveys (data obtained from 35 subjects over 22 universities). Those subjects that were able to match high expectations with high experiences are showcased on the webpages, with the co-ordinators describing the subject and reflecting on the reasons why they believe it succeeded in being highly regarded by students.

Workshops were instrumental in identifying indicators of good practice in service teaching. The discussions that took place and the indicators of good practice that emerged are to be found in the workshop reports which appear in the Project Documents section of the website.
Three refereed papers also emerged for this strand of the project, which deal with: 1) the model of service teaching that we identified through this project; 2) the findings of the expectations/experiences surveys as trialled at one large university; and 3) selected findings from the national data.

A document has been prepared which we believe will be of value to the tertiary physics education community in Australia. It comprehensively outlines the overall aims, the methodology used, the data collected, the findings and the conclusions to be drawn from the expectations/experiences surveys. This document is available on the project website (and forms Appendix 3 of this report). We intend to publish this document and to distribute it to physics departments nationally.

**Undergraduate experimentation**

- A project website containing effective and efficient laboratory and project programs, including ‘effective/motivating’ experiments.
- Workshops based around ‘effective/motivating’ experiments to engage the community in sharing materials.
- Document features of effective and efficient experimental programs within particular local contexts.

With respect to deliverables for the undergraduate experimentation strand, we have created webpages which include a large repository of senior level physics experiments, with short descriptions provided by physics academics from across Australia. Currently the repository contains almost 400 experiments covering fields as diverse as astronomy and fluids. In the *Project Documents* section of the project website, there are transcriptions of interviews with Prof. John Rice in which: a) he discusses the value of the ACELL approach to evaluating experiments, which articulates with our own project, and b) he relates in some detail the findings of the ACDS project on ‘Reconceptualising Tertiary Science Education for the 21st Century’, which examined the role of laboratories in undergraduate science education.

Two national workshops focusing of the undergraduate experimentation were organised (one at UTS and the other at Monash University). The first workshop trialled the ACELL methodology, as applied to physics experiments. Through the workshop, teaching materials were prepared for eight experiments (along with ancillary information as required by the ACELL protocol). Since the time of the workshop, two experiments have been taken up and adapted by academics from institutions other than those in which the experiments were created. The second workshop considered goals and possibilities for the higher year physics laboratories. Reports from both workshops can be found in the *Workshops* section of the website.

Two refereed papers emerged from this strand of the project which deal with: 1) the use of the chemistry laboratory work evaluation process ACELL as a tool for evaluating and improving physics laboratory work, and 2) the sharing of resources related to higher year level experiments, which are recognised as an issue for many departments and which have not previously received detailed consideration in the physics education sector.
Graduates in the workforce

- Profiles of physics graduates in the workforce, and what employers say about them, to be produced on flyers and websites (both project website and institutional websites).
- Document strengths of current physics education as well as the challenges faced in preparing students for actual destinations in the workforce, with feedback to departments, instructional designers, employers and student advisors.

With respect to deliverables for the graduates in the workforce strand, we have assembled webpages for this strand which include profiles of physics graduates who have found employment as diverse as an aircraft engineer, operational analyst and patent attorney. The webpages also contain a comprehensive listing of initial graduate jobs. The graduate and employer survey appear in the Survey Instruments section of the project website.

One non-refereed and one refereed paper emerged for this strand of the project. The first paper considered the question: “Why do Physics? Where does it really lead?” The second paper reported on the physics graduates and employers sampled by the surveys and focused primarily on one aspect of their responses: the graduate attributes developed during their physics education.

Active engagement of department heads, and cooperative interactions with the ACDS initiative

Heads of departments were actively engaged in the project through invitations to nominate academics to take part in the surveys. Findings of the surveys were fed back to the HODs and the academics involved. HODs were informed of the general progress of the project through regular email updates, including receiving copies of project documents, papers and analysis reports.

Heads of departments were informed of the outcomes of the project through an invited presentation that took place at the AIP Congress in December 2008 and which was attended by physics HODs from across Australia. Suggestions were made by the HODs regarding the ways in which wider dissemination could be facilitated (for example, the AIP taking on the role of managing and maintaining the project website once the project was completed).

Extensive interactions took place with the ACDS owing to our mutual interest in laboratories for undergraduates. In addition to meetings with the ACDS president and the project officer of their ALTC project ‘Reconceptualising Tertiary Science Education for the 21st Century’, there were two formal exchanges between a leader of each project (Les Kirkup and Professor John Rice) which were recorded and transcribed and which can be found in the Project Documents section of the project website.

Factors critical to the success

Crucial and timely support to get the project underway was provided by the Dean of Science at The University of Sydney, which allowed the project to start before any contract was formally agreed with the Carrick Institute, as well as providing funding to employ a project officer early in 2007. We also recognise the swiftness with which various financial and legal groups expedited the completion of the contract, once it was submitted to UTS.
Two project officers employed sequentially and with complementary skills, were needed to bring this project to a successful conclusion. On reflection, we were very fortunate that the right experience and skills were available at the right time. The importance of the project officer cannot be overstated and it is possible, when diverse skills and background are essential to a project (for example a background in educational development and the skills to construct an elaborate website), that it is unrealistic to find those capacities in a single person. We originally planned for more than one project officer and the project would have undoubtedly benefited if resources had been available to employ two people.

The project team has positive support from the larger university physics education network. The vast amount of data collected and the participation during the 18-month lifetime of the project is direct witness to the actual support. A critical factor is the foundation laid by the AUTC/Carrick Physics Project, funded by the predecessors of the ALTC. The first DBI funding provided to physics was in 2004. By 2009 we have managed to significantly lift the profile of teaching and learning among the heads of physics departments and the growing number of physics teaching staff motivated to join the project. What is needed now is to be able to harvest the data to get maximum benefit. There is a substantial amount of analysis and interpretation still to do and this needs funding.

**Factors that impeded progress**

The delay in signing the agreement hindered the project in the first six months. This delay was largely out of the control of the project leaders and was due primarily to the protracted and ultimately ineffective contract negotiations between the (then) Carrick Institute and The University of Sydney. This resulted in the financial reporting and management of the project moving to UTS in September 2007.
Recommendations for further development
There is an aspect of the service teaching strand that is a candidate for vigorous investigation.

Owing to the overwhelming evidence obtained nationally of negative student experiences in service teaching laboratories, we should evaluate physics experiments for service subjects. Such a study should focus on those subjects that successfully link the laboratory program in the service subjects to the areas of the students’ majors. The study should also consider the special professional development requirements of casual academics involved in demonstrating in laboratories that form part of a physics service subject.

The work on learning in laboratories needs to be funded. It is pleasing to note that the EOIs related to this have been approved and we are hopeful that both will be funded by the ALTC. One project focuses on physics, the training of tutors and development of entire programs. The other focuses on science (with physics as a component), individual experiments and their learning outcomes.

A considerable amount of data has been collected in the current project. Further analysis and interpretation is necessary at the national level (macro analysis) and at institutional level (micro analysis). Funding for the project officer to work for six months to a year on this analysis would be invaluable.
REFERENCES


ACKNOWLEDGEMENTS

This project would not have been possible without the support of the Australian Learning and Teaching Council. The project was co-ordinated from the Department of Physics and Advanced Materials at the University of Technology Sydney and the School of Physics at the University of Sydney. The provision of facilities and resources by these institutions is acknowledged and greatly appreciated.

The authors would also like to gratefully acknowledge the contributions made to the project by the following people and organisations:

- Physics Heads of Departments (or equivalent) throughout Australia
- The Australian tertiary physics community – all departmental contacts, subject co-ordinators, lecturers, academics and convenors
- Australian Institute of Physics past and present presidents – Cathy Foley and Brian James
- Advancing Chemistry by Enhancing Learning in the Laboratory (ACELL) – Justin Read, Scott Kable and other ACELL directors
- Australian Council of Deans of Science (ACDS) project leaders – John Rice and Sue Thomas
- Australian Learning and Teaching Council (ALTC) past and present staff – Jan Orrell, Denise Chalmers, Neridah Baker and Julie Adams
- Planning and Quality Unit at UTS – Antoine Goarin and staff
- Faculty of Science staff at UTS – Narelle Smith
- Undergraduate students that participated in service teaching surveys and workshops
- Graduates that participated in Graduates in the workforce surveys
- Employers that participated in Graduates in the workforce surveys
Appendix 1
Pro formas or other material produced for or used in the initiative

Service Teaching Strand
Survey A (Expectations)

QUESTIONNAIRE A

I am majoring in: __________________________________________

This questionnaire is part of a study into physics subjects taken by students not majoring in physics. We would like you to respond to the statements below and ask you not to put your name on this survey. You can choose to not fill in this questionnaire, or to hand in a questionnaire that is blank. All responses remain anonymous. You are free to withdraw from participating in this study at any time without giving a reason. Any person with concerns or complaints about the conduct of a research study can contact the Manager, Research Ethics Office, University of Technology Sydney on (02) 9514 5616 (telephone); (02) 9514 1344 (facsimile) or hadiza.yunusa@uts.edu.au (email).

Please mark each of the statements below to indicate to what extent you agree with the statement:

<table>
<thead>
<tr>
<th>Shade Circles Like This:</th>
<th>NEA</th>
<th>Strongly Strongly</th>
<th>Agree</th>
<th>Disagree</th>
<th>Strongly</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NEA</td>
<td>Strongly Strongly</td>
<td>Agree</td>
<td>Disagree</td>
<td>Strongly</td>
</tr>
</tbody>
</table>

1. It is apparent to me that this subject is a valuable part of my degree.
2. Only people with an extraordinary ability are capable of understanding physics.
3. I am keen to see how this subject links to my major area of study.
4. I believe an understanding of physics will benefit my studies in other areas of my degree.
5. I am confident that my mathematics background is sufficient for me to be successful in this subject.
6. I expect to do well in class tests in this subject.
7. I am looking forward to doing labs in this subject.
8. If it were possible, I would have avoided taking this subject.
9. I expect the links between this subject and my major area of study to be made obvious throughout the semester.
10. I expect to have to work harder in this subject than in my other subjects this semester.

Please answer the following questions:

11. What final grade are you aiming for in this subject?
   - [ ] Pass
   - [ ] Credit
   - [ ] Distinction
   - [ ] High Distinction
   - [ ] Don’t know yet

12. Did you study Physics to Year 12 at school?
   - [ ] Yes
   - [ ] No

13. Please describe briefly any particular expectations you have as you begin your study in this subject. If you need more space, please write on the other side of this questionnaire.

Thank you for completing this survey.

Forging new directions in physics education in Australian universities
Appendix 1 - Pro formas or other material produced for or used in the initiative
Survey B (Experiences)

QUESTIONNAIRE B

I am majoring in: ________________________________

This questionnaire is part of a study into physics subjects taken by students not majoring in physics. We would like you to respond to the statements below and ask you not to put your name on the survey. You can choose to not fill in this questionnaire, or to hand in a questionnaire that is blank. All responses remain anonymous. You are free to withdraw from participating in this study at any time without giving a reason. Any person with concerns or complaints about the conduct of a research study can contact the Manager, Research Ethics Office, University of Technology Sydney on (02) 9514 8915 (telephone); (02) 9514 1264 (facsimmie) or rdo@uts.edu.au (email)

Please mark each of the statements below to indicate to what extent you agree with the statement.

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<thead>
<tr>
<th>Shade Circle Like This:</th>
<th>Not Like This:</th>
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1. It is apparent to me that this subject is a valuable part of my degree.
2. Only people with an extraordinary ability are capable of understanding physics.
3. There are clear links between this subject and my major area of study.
4. I believe an understanding of physics will benefit my studies in other areas of my degree.
5. I am confident that my mathematical background is sufficient for me to be successful in this subject.
6. My achievements in class tasks in this subject exceeded my expectations.
7. The labs in this subject were a positive learning experience.
8. I would advise others to avoid taking this subject if at all possible.
9. The lecturers succeeded in linking this subject to my major area of study.
10. I worked harder in this subject than for my other subjects this semester.

Please answer the following questions:

11. What final grade are you aiming for in this subject?
   - [ ] Pass
   - [ ] Credit
   - [ ] Distinction
   - [ ] High Distinction
   - [ ] Don't know yet

12. Did you study Physics to Year 12 at school?
   - [ ] Yes
   - [ ] No

13. Please describe briefly your experience of this subject, and in particular, what you think might be done to improve the subject. If you need more space, please write on the other side of this questionnaire.

--------------------------------------------------------------------------------------

Thank you for completing this survey.
Graduates in the Workforce Strand

Graduate Survey

Carrick Physics Graduate Survey 2008

Introduction

The Carrick Institute for Learning and Teaching in Higher Education has funded a project on physics teaching in universities as part of its Discipline-based Initiatives Scheme. As part of this project, Dr John O’Byrne from the University of Sydney is leading a working party concentrating on physics graduates in the workforce, which is the subject of this questionnaire.

This questionnaire is divided into 5 parts in addition to this Introduction:

1. Basic Information
2. Career Information
   - Job Immediately After Graduation
   - Current or Most Relevant Job
   - Recommendations
3. UNDERGRADUATE Physics Experience
4. POSTGRADUATE Physics Experience (if applicable)
5. Any other comments?

We would appreciate your effort to fill in this questionnaire as completely as possible (taking around 20 minutes) but will appreciate any information you can supply.

Some points to note:
- The questionnaire must be completed in one go, although you can move back and forth through the pages.
- You may prefer to complete a paper copy that can be obtained from the Project Officer at the address below.

Thank you for your participation.

Any questions about completing the survey or the larger project should be directed to:

Alberto Mendez
Carrick Project Officer,
School of Physics,
University of Sydney
(02) 9351 5961 (Telephone)
(02) 9351 7726 (Facsimile)
a.mendez@physics.usyd.edu.au

Information about the survey process can be found in the Participant Information Statement and the Consent Form. Submitting your responses to the questionnaire will imply acceptance of the terms of this consent form.

Any person with concerns or complaints about the conduct of a research study can contact:

The Senior Ethics Officer,
Ethics Administration,
University of Sydney
(02) 9351 4811 (Telephone)
(02) 9351 6/06 (Facsimile)
gbrody@usyd.edu.au
## 1. Basic Information

1. **Name (optional)**

2. **Email address (optional)**

3. **Age**

4. **Gender**
   - Female
   - Male

5. **Why did you decide to do Physics at university?**

6. **Degrees completed**

   Please provide the name of ALL degrees completed, the institution at which you studied and the year conferred.

<table>
<thead>
<tr>
<th>Degree</th>
<th>Institution</th>
<th>Year</th>
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</thead>
<tbody>
<tr>
<td>1st Degree</td>
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<tr>
<td>4th Degree</td>
<td>Institution</td>
<td>Year</td>
</tr>
</tbody>
</table>

7. **Are there any explanatory comments you wish to make in describing your degrees?**

---

For the Carrick Physics Graduate Survey 2008, the page is focused on collecting basic information from graduates, including their name, email, age, gender, and reasons for choosing Physics. It then asks for details of their degrees completed, including the name of the institution and the year the degree was conferred. Finally, it invites them to provide any additional comments about their degrees.
# Carrick Physics Graduate Survey 2008

## 2.1 Career Information 1 (Job Immediately After Graduation)

Please describe your first full-time (if appropriate) job - i.e. the primary job you began immediately after graduation/completion of your degree.

1. **Your description of your first job after graduation**
   
2. **Title of your position (if applicable)**

3. **Organisation/Company name**

4. **Your description of Organisation/Company’s area of activity/business**

5. **Main location of your job (state and/or country)**

6. **Full time or part time?**
   - [ ] Full time
   - [ ] Part time

7. **What year did you start and how long were you in this job?**
   - Year started: \_
   - Number of years: \_

8. **Any explanatory comments you wish to make concerning this job?**

---

Forging new directions in physics education in Australian universities

Appendix 1 - Pro formas or other material produced for or used in the initiative
### Carrick Physics Graduate Survey 2008

#### 2.2 Career Information 2 (Current or Most Relevant Job)

Please describe your current job or whichever job you have had that best represents your career (not necessarily because of its Physics connections).

1. **What job are you describing?**
   - [ ] Current
   - [ ] Most relevant

2. **Your description of the job**

3. **Title of your position (if applicable)**

4. **Organisation/Company name**

5. **Your description of Organisation/Company’s area of activity/business**

6. **Main location of your job (state and/or country)**

7. **Full time or part time?**
   - [ ] Full time
   - [ ] Part time

8. **What year did you start and how long have you been in this job?**
   - Year started
   - Number of years

9. **Any explanatory comments you wish to make concerning this job?**
### Carrick Physics Graduate Survey 2008

#### 2.3 Career Information 3 (Recommendations)

1. Would you recommend a major in Physics in undergraduate studies (usually 3 years study) as useful training for a career in your current field?
   - [ ] Yes
   - [ ] No

2. If you answered NO to the previous question, would you recommend a smaller component of Physics (not a major) in undergraduate studies as useful training for a career in your current field?
   - [ ] Yes
   - [ ] No

3. Please briefly explain your answers to the previous two questions

```markdown

```
### Carrick Physics Graduate Survey 2008

#### 3. UNDERGRADUATE Physics Experience

Note: In all the following 'Physics' should be interpreted broadly. Perhaps your degree had another name and a broad interpretation is more appropriate to your experience.

1. **What features of your undergraduate Physics studies were of most help to your learning?**

2. **What features of your undergraduate Physics studies were NOT helpful to your learning?**

3. **How important to your learning was your undergraduate Physics education compared to the rest of your undergraduate courses?**

4. **Is it an advantage having done undergraduate Physics?**
   - Do you think you have an advantage over graduates from other disciplines? How?
   - Are there special knowledge and skills that undergraduate Physics provides?
## Carrick Physics Graduate Survey 2008

### 5. Graduate attributes

Please complete the following table by choosing the description that best represents the level to which a particular attribute was developed in your undergraduate Physics studies.

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</table>

### 6. Do you think any of these attributes needed to be developed more in your undergraduate Physics studies? If so, please indicate that by ticking one or more boxes in the table below.

<table>
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### 7. Were any of these attributes better developed in another of your undergraduate courses?

[Blank space for response]
## Carrick Physics Graduate Survey 2008

### 4. POSTGRADUATE Physics Experience (if applicable)

Note: Please complete the following section if you also have a postgraduate degree in Physics (again interpreted broadly if necessary).

1. What features of your postgraduate Physics studies were of most help to your learning?  
2. What features of your postgraduate Physics studies were NOT helpful to your learning?  
3. How important to your learning was your postgraduate Physics education compared to the rest of your undergraduate and postgraduate courses?  
4. Is it an advantage having done postgraduate Physics? Do you think you have an advantage over graduates from other disciplines? How? Are there special knowledge and skills that postgraduate Physics provides?
### Carrick Physics Graduate Survey 2008

**5. Graduate attributes**

Please complete the following table by choosing the description that best represents the level to which a particular attribute was developed in your postgraduate Physics studies.

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<tr>
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**6. Do you think any of these attributes needed to be developed more in your postgraduate Physics studies? If so, please indicate that by ticking one or more boxes in the table below.**

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</table>
5. Any other comments?

1. Are there any other comments you would like to make that you think may be relevant to our survey?

For example, you may have comments on the following:

- jobs held by Physics graduates,
- how appropriate Physics training is to a lifetime of employment,
- career information you accessed/were given as a student, and
- career information you would have found useful as a student?

* 2. (must be answered)

Would you be willing to participate in an interview to probe some of these questions a little more closely?

The interview would probably take about 30 minutes and be done in person or by phone, depending on what arrangement proved to be mutually convenient.

In some cases, if you agree, the interview could also serve as the basis of a profile to be used on a web page or a brochure. These profiles provide concrete examples of the diverse range of careers pursued by Physics graduates.

- [ ] Yes
- [ ] No
**Carrick Physics Graduate Survey 2008**

3. *(must be answered)*

We have also designed a questionnaire for employers of physics graduates, seeking their views on the value of employees with a Physics education.

We need your cooperation in identifying and contacting them, so it would be greatly appreciated if you could ask your employer(s) (present and/or past) if they are willing to help.

Are you willing to approach your employer, or have us approach them, to direct them to the webpage and the questionnaire?

- Yes
- No

If Yes, please provide a contact name and contact details (email, phone or postal) for your employer. This will tell us who you have asked, or who we need to ask.
### Carrick Physics Employer Survey 2008

#### Introduction

The Carrick Institute for Learning and Teaching in Higher Education has funded a project on physics teaching in universities as part of its Discipline-based Initiatives Scheme. As part of this project, Dr John O’Byrne from the University of Sydney is leading a working party concentrating on physics graduates in the workforce, which is the subject of this questionnaire.

This questionnaire is aimed at employers who have recently (in the last 5 years) hired staff with undergraduate or postgraduate degrees in Physics. We’d like to gauge your opinions on the value of undergraduate or postgraduate degrees in Physics as demonstrated by your employee(s).

This questionnaire is divided into 4 parts in addition to this Introduction:

1. **Basic Information**
2. **UNDERGRADUATE Physics Employees**
3. **POSTGRADUATE Physics Employees (if applicable)**
4. **Any other comments?**

We would appreciate your effort to fill in this questionnaire as completely as possible (taking around 20 minutes) but will appreciate any information you can supply.

Some points to note:
- The questionnaire must be completed in one go, although you can move back and forth through the pages.
- You may prefer to complete a paper copy that can be obtained from the Project Officer at the address below.

Thank you for your participation.

Any questions about completing the survey or the larger project should be directed to:

Alberto Mendez  
Carrick Project Officer,  
School of Physics,  
University of Sydney  
(02) 9351 3961 (Telephone)  
(02) 9351 7726 (Facsimile)  
amendez@physics.usyd.edu.au

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University of Sydney  
(02) 9351 4811 (Telephone)  
(02) 9351 6706 (Facsimile)  
gbh@syd.usyd.edu.au

---

**Page 1**
### Carrick Physics Employer Survey 2008

**1. Basic Information**

1. **Name (optional)**
   - [Field]

2. **Email address (optional)**
   - [Field]

3. **Organisation/Company name**
   - [Field]

4. **Your description of Organisation/Company’s area of activity/business**
   - [Field]
### Carrick Physics Employer Survey 2008

#### 2. UNDERGRADUATE Physics Employees

Please complete the following section describing your experience of graduates with (only) an undergraduate degree in 'Physics'. It might help to concentrate on 2 or 3 Physics graduates who have worked for you in the last few years.

**Note:** In all the following 'Physics' should be interpreted broadly. Perhaps your employee's degree had another name and a broad interpretation is more appropriate to his/her experience.

1. Please describe the jobs performed by Physics graduates in your Company/Organisation

2. Are there special knowledge, skills and approaches that Physics graduates bring to the job?

3. Please comment on the ability of Physics graduates to learn and adapt

4. How could Physics graduates be better suited to your Company/Organisation?

5. How well do Physics graduates learn and adapt compared to graduates from other disciplines?

6. After a couple of years of employment, are Physics graduates different from those from other disciplines? If yes, in what way?

7. Would you employ a Physics graduate in preference to those from other disciplines? Why or why not?
### Carrick Physics Employer Survey 2008

#### 8. Graduate attributes

Please complete the following table by choosing the description that best represents the level to which your employee(s) with (only) an undergraduate degree in 'Physics' demonstrate a particular attribute, as gauged at the start of their employment with you, i.e. the attributes they brought to the position.

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#### 9. Do you think any of these graduate attributes needed to be developed more in undergraduate physics studies? If so, please indicate that by ticking one or more boxes in the table below.

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#### 10. Please explain why you have chosen these attributes for further development in undergraduate Physics studies

[Blank space for answer]
Carrick Physics Employer Survey 2008

11. Is it reasonable to expect university graduates to come with these attributes or are they better learnt/developed at work?

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<tr>
<th>Attribute</th>
<th>Yes</th>
<th>No</th>
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### Carrick Physics Employer Survey 2008

#### 3. POSTGRADUATE Physics Employees (if applicable)

Please complete the following section describing your experience of graduates with a postgraduate degree in Physics. It might help to concentrate on 2 or 3 Physics graduates who have worked for you in the last few years.

Note: In all the following ‘Physics’ should be interpreted broadly. Perhaps your employee’s degree had another name and a broad interpretation is more appropriate to his/her experience.

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5. How well do Physics graduates learn and adapt compared to graduates from other disciplines?

6. After a couple of years of employment, are Physics graduates different from those from other disciplines? If yes, in what way?

7. Would you employ a Physics graduate in preference to those from other disciplines? Why or why not?
## Carrick Physics Employer Survey 2008

### 8. Graduate attributes

Please complete the following table by choosing the description that best represents the level to which your employee(s) with a postgraduate degree in 'Physics' demonstrate a particular attribute, as gauged at the start of their employment with you, i.e. the attributes they brought to the position.

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<td>problem solving</td>
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<td>teamwork</td>
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<tr>
<td>consideration of ethical and social issues</td>
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<td>laboratory skills</td>
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<td>experimental design</td>
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<td>computational skills</td>
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<tr>
<td>information retrieval</td>
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</tbody>
</table>

### 9. Do you think any of these graduate attributes needed to be developed more in postgraduate Physics studies? If so, please indicate that by ticking one or more boxes in the table below.

<table>
<thead>
<tr>
<th>Attribute</th>
<th>need more</th>
</tr>
</thead>
<tbody>
<tr>
<td>oral communication</td>
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<tr>
<td>written communication</td>
<td></td>
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<tr>
<td>problem solving</td>
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<td>teamwork</td>
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<tr>
<td>consideration of ethical and social issues</td>
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<td>laboratory skills</td>
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<td>experimental design</td>
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<td>project planning</td>
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<td>research methodology</td>
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<tr>
<td>computational skills</td>
<td></td>
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<tr>
<td>information retrieval</td>
<td></td>
</tr>
</tbody>
</table>

### 10. Please explain why you have chosen these attributes for further development in postgraduate Physics studies

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Forging new directions in physics education in Australian universities
Appendix 1 - Pro formas or other material produced for or used in the initiative
### Carrick Physics Employer Survey 2008

11. Is it reasonable to expect university graduates to come with these attributes or are they better learnt/developed at work?
Carrick Physics Employer Survey 2008

4. Any other comments?

1. Are there any other comments you would like to make that you think may be relevant to our survey?

For example, you may have comments on the following:

- jobs held by Physics graduates
- how appropriate Physics training is to a lifetime of employment

2. (must be answered)
Would you be willing to participate in an interview to probe some of these questions a little more closely?

The interview would probably take about 30 minutes and be done in person or by phone, depending on what arrangement proved to be mutually convenient.

In some cases, if you agree, the interview could also serve as the basis of a profile to be used on a web page or a brochure. These profiles provide concrete examples of the diverse range of careers pursued by Physics graduates.

☐ Yes
☐ No
Appendix 2
EXTERNAL EVALUATION BY AUSTRALIAN COUNCIL of DEANS of SCIENCE

The ALTC Discipline Based Initiative project ‘Forging new directions in physics education in Australian universities’ builds on substantial previous work of the AUTC project ‘Learning Outcomes and Curriculum Development in Physics’. Quite apart from new directions, these projects have forged a national community of practice around tertiary physics education focusing ‘the energy of this community’ on critical questions for the development of physics teaching and learning in the national system.

The project leaders made a very insightful choice of the areas that ‘Forging new directions …’ would concentrate on. Each of them, ‘Service Teaching’, ‘Undergraduate Experimentation’ and ‘Graduates in the Workforce’, are central to reconceiving the nature of tertiary physics education for the current student population, only a tiny proportion of which will become physicists in any traditional sense.

Service teaching is well established in physics departments, and well understood as an education in physics for those who will not become physicists. The project surveys and workshops for this area opened up the question of the effectiveness of this kind of teaching. This is important for physicists, since it appears that they, like most science academics, still focus their educational role on teaching people how to be physicists (or scientists in general) and to bring them to a love of their subject for its own sake. If instead they were to treat their undergraduate classes as being 95% service students it would bring a very different and perhaps more engaging perspective.

The survey results compared classes designed specifically for service students with those that were not. It found very little difference between the two with respect to student appreciation. Workshop participants found this result highly counterintuitive. An experiment that produces a counterintuitive conclusion is extremely attractive to physicists, and experimental scientists more generally, and this work stands to focus the interest of physics educators for some time. It is a major outcome of the project.

Academic physicists will be delighted if custom design of courses can be proved to be of no significant effect on the customers, because in that case they need no longer spend their time on it. My own view is that the null result probably reflects a significant lack of custom design in service courses, in which customisation is often equated with ‘dumbing down’. This dichotomy should be explored in further work.

The workshops on undergraduate experimentation have produced two highly significant outcomes. The first is an agreement to publish a database of undergraduate physics experiments. This will remove considerable duplication of
effort, but also provide a compendium of ideas for experiments that that could, over time, reach into the secondary school sector.

The second outcome is expansion of the ACELL system of educational design and quality testing of chemistry experiments into physics (and in fact into biology as well). The project held a day workshop to trial the ACELL methodology for physicists, which generated a lot of interest and constructive ideas about how the system could be adapted for physics experiments and improved in general.

It is here that the project made the greatest contact with the ACDS DBI Pilot scheme grant ‘Reconceptualising Tertiary Science Education for the 21st Century’. One of the major findings of the ACDS project was the lack of explicit learning goals for laboratory programs overall and the lack of explicit educational reflection that occurs in them. The ACDS project identified the ACELL process as a partial remedy for this, and the ‘Forging new directions …’ project took up this idea with enthusiasm. It also held workshops which produced a great deal of positive reflection on the higher level learning goals of laboratory programs.

The ‘Graduates in the Workforce’ surveys also produced a significant outcome of the contra-indicative kind. The issue that stood out was that the majority of those surveyed in the workforce that could be identified as physics graduates using their physics were academics. It proved very difficult to track down physics graduates in non-academic employment.

In my view this is due neither to a failure of the survey process nor of Australian universities to keep good track of alumni. I think it reflects the fact that physics is seen as an academic occupation, and the idea of a person being valuable to employers in industry as a physics graduate is highly arguable.

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. The group now needs more influence among science faculties across the country. The ACDS is in a position to promote that, both because of its role and constitution, and because of the good working relationships established through the project.

Prof. John Rice
Executive Director, ACDS
1. Preamble

Our goal in the service teaching strand of this project is to reach consensus about what constitutes good practice in service teaching in physics. We intend to identify such practice in Australian universities and disseminate our findings through workshops involving physics academics and contact with discipline leaders, such as HODs and the Australian Council of Deans of Science (ACDS). We also intend to disseminate elements of this work through a website and papers presented at national conferences.

Through service teaching, the tertiary physics community in Australia connects with many thousands of students each year. Physics service subjects have a key role to play in the development of graduate capabilities such as the capacity to learn in, and from, a diversity of disciplines in order to enhance the application of scientific knowledge and skills in professional contexts.

Students in service subjects carry with them their experiences of physics, which affects the esteem in which physics is held by an influential community of university-educated citizens. Other reasons for concentrating on physics service teaching include acknowledging the growing importance of contributions that physics makes to other disciplines and the fact that the financial well-being of most Australian physics departments is tied to their service teaching.

Our study brings an emphasis to the student voice, as we explore what is meant by good practice in service teaching, where such practice is occurring, and the factors that allow good practices to flourish within a physics department. In particular, we are keen to examine the question ‘what impact does a semester of physics have on students not intending to major in physics?’ Through a consideration of students’ expectations and experiences of service subjects, we are intent on identifying and promoting indicators of good practice.

Much data were gathered through the surveys. We do not present an exhaustive analysis of the data gathered, but we do draw out some important issues that deserve further consideration.

We would like to thank our fellow academics and students from around Australia who gave generously of their time to support and actively engage with this project. They have done much to maintain physics service teaching in Australia on the teaching and learning agenda.

Through the service teaching strand of this project, we have:
- Reviewed service subject teaching materials from twelve universities.
- Identified models of physics service teaching.

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1 Graduate attribute adapted from UTS Science.
• Engaged the physics community in identifying and ranking indicators of good practice in service teaching.
• Devised, trialled and analysed students’ expectations/experiences surveys of service subject.
• Identified links to major and laboratory experiences as key issues emerging from the surveys.
• Communicated findings of this strand of the project at four workshops in three state capitals.
• Published student surveys on the project website.
• Published three peer-reviewed conference papers on this work.
• Distributed to academics the findings from the expectations/experiences surveys, both for their own subjects as well as for all 35 subjects.
• Invited subject co-ordinators (or equivalent), of subjects in which high student expectations were matched by equally high student experiences, to describe their subjects for inclusion on the project website as well as through a presentation at a national workshop.
• Disseminated findings of the project to Australian HODs at the biennial national Australian Institute of Physics (AIP) Congress held in Adelaide in December 2008.
• Obtained feedback from academics on the merit and value of the surveys.

2. Background

Physics and physicists have an image problem, especially among those not majoring in physics, but who are nevertheless required to enrol in a semester of physics to fulfil course requirements. Physics is perceived by many students as being a collection of complex facts; dull, and with little connection to today’s world (Cheary et al., 1995; Fonseca and Conboy, 1999; Guisalsola et al., 2002). Physicists remain stereotyped as middle-aged bearded men, wearing white coats, surrounded by equipment and writing neatly in notebooks (McDonnell, 2005).

Dissatisfaction with physics subjects delivered to non-physics majors has a long history (Caswell, 1934; Lapp, 1940) and though many approaches aimed at addressing the situation have been proposed, fervently-held negative views affecting engagement with physics have withstood attempts at serious reformation. Clues as to why this might be expected can be found in a study carried out by Sheila Tobias almost two decades ago (Tobias, 1990). Tobias found that the absence of community, large class sizes, and lack of contagious enthusiasm, conspire to turn even extremely bright and intellectually hungry students away from physics.

Though there is generally a shared understanding of the term service teaching (at least within Australian universities), there are differences of opinion regarding which subjects should be classified as service subjects. For example, a service subject could be described as one delivered to majors drawn from another school or faculty (such as a Faculty of Engineering). Other descriptions would include physics subjects delivered to students within a school or faculty (for example, physics taught to medical science students in the Faculty of Science).

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2 Some of the material in this section may be found in published papers (Kirkup et al., 2007, Kirkup et al., 2008).
A useful definition of service teaching was included in the 2004/5 AUTC study ‘Learning Outcomes and Curriculum Development in Physics’ (Mills et al., 2005).

A physics service subject is one delivered, maintained and assessed largely by a department of physics, specifically designed for non-physics majors....

In this report we make the distinction between subjects routinely enrolling both physics majors (PMs) and non-physics majors (NPMs), often referred to as mainstream subjects, and those enrolling only NPMs, which would normally be regarded as service subjects.
2.1 Impact and scope of physics service teaching

There are several reasons why the issue of provision of physics to NPMs, while far from being new, deserves to remain a matter that attracts serious and sustained attention by the physics community in Australia. Those reasons include:

- Those who were NPMs at university deliver a significant fraction of the teaching of physical principles in primary and secondary schools, both public and private, and will continue to do so for the foreseeable future. A recent study showed that one in four senior high school physics teachers in Australia had not studied physics beyond first year, and almost 43% of high school physics teachers lacked a physics major (Harris et al., 2006). These NPMs are emissaries for the physics discipline in schools, with the vital role of increasing the awareness of physics’ contribution to society. Their experiences of physics at university (which may be limited to a single semester of physics) will shape their attitudes towards physics and, by natural extension, those of the students that they teach.

- As a physics community we have a precious (and in some cases a final) opportunity to promote physics to students who are destined to major in disciplines as diverse as physiotherapy, civil engineering and forensic science.

- There is a growing awareness of the importance of physical thinking, for example in the biological sciences, and that recent developments in this area are urging greater reliance on quantitative approaches to science of the type promoted by physicists. As Bialek and Botstein expressed it (Bialek and Botstein, 2004):

  …the fragmented teaching of science still leaves biology outside the quantitative and mathematical structure…this strikes us as particularly inopportune at a time when opportunities for quantitative thinking about biological systems are exploding…

- In first year, where by far the greatest number of students encounter physics, their initial experiences are crucial and influence the extent to which they are prepared to persist with their studies (Pitkethly and Prosser, 2001). Science in the U.S., for example, has been shown to lose 40% to 60% of students with higher than average abilities within two years of entering college or university. The retention rate worsens when minority groups are considered. The educational experience and the culture of the discipline as communicated to students have a major influence on student retention (Seymour and Hewitt, 1997). First year physics service subjects, which reach many thousands of students annually in Australia, have a sizeable potential to affect (for the good or otherwise) retention rates in science and engineering.

- The economic imperative cannot be ignored by Australian physics departments, as all teach a significant number of NPMs. Pollard et al. (2006) reported that half of the physics departments in Australia rely on their service teaching for more than 50% of their income. Service teaching has become increasingly critical as the amount of money available to physics departments to support teaching has declined over the past decade, affecting, for example, staff numbers. Staff numbers have declined
in Australia from in excess of 350 in 1994 to under 250 in 2002. Physics departments, for example those in the UK, who have ignored service teaching or never had such teaching to fall back on in lean times, have been downsized or closed altogether. To emphasise the seriousness of the situation: in 1994 there were 79 physics departments in the U.K. By 2005 that figure had fallen to 48 (Parliamentary Office of Science and Technology, 2007).

- The number of NPMs taught in every Australian university physics department exceeds that of PMs. As an example, at a Sydney research-based university, around 1000 students enrol in first year physics subjects and of these only ~100 continue on and major in physics. The NPMs are ambassadors for physics. Those that take up leadership roles in business, industry and politics, have opportunities to influence strategic policies which have the potential to impact on physics as a discipline and science in general. Negative or disheartening experiences of physics can only prejudice the physics community when such leaders begin to exercise their authority and influence.

There are contemporary drivers for change in undergraduate teaching which form a backdrop to a review or revitalisation of physics service teaching. For example, the adoption and development of models which are outcomes of the Bologna Process, is fuelling the debate about generalist as opposed to specialist first degrees.

Impact of the Research Quality Framework (RQF) and the Excellence in Research for Australia (ERA)

The escalating focus on research carried out by universities in Australia which is partly a consequence of first the RQF, and more recently the ERA, has encouraged universities to divert or redistribute scarce resources to maximise support for research. For some time to come this cross-subsidisation of research will have an unquantifiable effect on teaching and learning at universities. Possible outcomes of the diversion of resources are: rationalisation of subjects resulting in increased class sizes, especially in the first year where service teaching dominates; reduced focus on curriculum reform and teaching developments; and increased teaching workloads for those designated as research inactive staff. There is evidence that a similar initiative in the U.K. called the Research Assessment Exercise (RAE), which has been carried out over the past 16 years, has been responsible for an unwelcome distortion of values in the U.K. higher education system, leading to reduced emphasis on teaching and learning matters (Jenkins, 1995; Banatvala et al., 2005).

The Bologna Process

In Europe, the Bologna Process is driving reforms to secure consistency and portability of qualifications (allowing, for example, credit transfer between higher degree institutions). It is recognised that this process will have a major influence on the development of higher education around the world (DEST, 2007). The Bologna Process favours the creation of general bachelor degrees (3 years, full time) followed by master degrees (2 years, full time), which are more specialised and professional in orientation. If higher education policy makers in Australia are convinced by the Bologna Process, it is not difficult to imagine general science degrees in Australia increasing in number. These degrees may be expected to have physics as a core component, which in turn would lead to many more...
NPMS studying the subject, at least in the first year. Already in Australia, the University of Melbourne has introduced major changes to its bachelor degrees which are now based on six broad undergraduate programs followed by a professional graduate degree (The University of Melbourne, 2007). These changes may be seen as congruent with some of the recommendations to emerge from the Bologna Process and provoke other higher education providers in Australia to re-evaluate their offerings at the bachelor level. It is timely to examine the extent to which serious ‘buy in’ to the Bologna Process and the models of provision of undergraduate courses that flow from the process, necessitate a rethink of the physics curriculum in general at the undergraduate level, and especially in the first year (though we do not attempt that examination here).

3. Methodology of characterising current models of teaching physics to NPMS

We began our consideration of physics service teaching by canvassing the members of the service teaching working party and heads of departments about the current state of service teaching within their universities. The purpose of this was to obtain an up-to-date snap-shot of current practices in a diversity of institutions, which would inform an analysis of the types of physics service subjects extant in Australian universities. We were also anticipating that since the AUTC study on ‘Learning Outcomes and Curriculum Development in Physics’ (Mills et al., 2005), changes might have occurred in some institutions as a consequence of staff reductions and the resulting consolidation of subjects. Indeed, one head of department reported that due to such pressures, large numbers of engineering students were enrolled in mainstream physics subjects for the first time in 2007.

Nine universities representing metropolitan and regional universities from New South Wales, South Australia, Western Australia and the Australian Capital Territory (ACT) responded to a short survey as follows (questions in bold):

*Where do your non-physics majors come from (i.e. are they mainly from another faculty, such as engineering, or are they within your faculty, e.g. physics taught to environmental science students)?*

Eight out of nine universities indicated that greater than 50% of their teaching to non-physics majors was taught to engineering students. Other significant contributors to the teaching load include students majoring in physiotherapy, general science and the biological sciences.

*Are non-physics majors taught together with physics majors?*

Of the universities surveyed, there were no first year (or first level) subjects which were populated solely by physics majors. Physics majors were either taught together with engineers (six universities) or with other science students (three universities).

*Is your service teaching mainly to first years?*
All nine universities canvassed indicated that service teaching was provided mainly to first years. Six universities indicated that a small amount of service teaching was provided beyond first year.

_Is there anything special that distinguishes your teaching of non-physics majors compared to your teaching of physics majors?_

Of the six universities that responded to this question, two indicated that there was no special distinction:

"We aim to do the best we can for all!"
"There are no differences where engineers and science students are co-taught."

Four universities indicated that extra maths/physics tutorials were provided, usually on an optional basis:

"For those with poor maths/physics background, we run drop-in tutes and extra lectures on some topics (although these classes may be attended by 'non service' students)."
"Extra maths support is offered as optional tutorials."
"Voluntary tutorials are available."
"There is a support programme for weak students comprising one extra tutorial each week."

_Is physics embedded within first year subjects not described as physics subjects? If so who teaches the physics component?_

Three out of nine universities indicated that a substantial amount of physics was embedded within first year (engineering) subjects taught by engineering schools/faculties and not by the physics department.

The findings of this snap-shot align with those of the AUTC study on ‘Learning Outcomes and Curriculum Development in Physics’ (Mills et al., 2005), which emphasised the importance of service teaching, and the regard it is held in by Australian physics departments who continue to be financially dependent on teaching to NPMs.

Subjects enrolling non-physics majors are diverse in content and mission. In order to reasonably assess that diversity, we collated material from 42 physics subjects in twelve universities representing universities from New South Wales (3), Queensland (3), Victoria (2), the ACT (2) and Western Australia (2). The materials reviewed included subject/unit outlines for all subjects, lab manuals for 21 subjects and assignments/exams for 20 subjects.

The diversity in both level and content of what is taught to NPMs is large. For those subjects which enrolled both PMs and NPMs there is clear evidence of rigor being maintained, with the role of mathematics being emphasised. This is nicely summed up by a quote from the subject outline of one mainstream physics subject which enrols large numbers of NPMs.

*This is not a course about physics* (original emphasis) – *it is physics. Students learn physics by doing it, by solving problems, whether on paper or in the lab. Concepts and principles are learned in context, by example and then by_
development. It is important to understand the limits of applicability. Mathematical skills … are essential tools in much problem solving. However, the art of problem solving in physics is understanding the principles and where they apply, and how and when to use them and the relevant mathematics or other tools.

Extract from subject outline for subject enrolling both PM and NPMs at a metropolitan university

Service subjects enrolling NPMs only, exhibit a diversity of content and approaches. They include those offering a general introduction to physics, generally at a lower conceptual level than those subjects enrolling PMs, to those for which the curriculum is much more aligned to the areas in which the NPMs were majoring. The following excerpts taken from the learning outcomes/objectives of two subjects (from different universities) are an indication of the diversity found amongst subjects delivered solely to NPMs.

From the outline of a general subject for NPMs:

On completion of this unit you should be able to demonstrate your achievement in the following learning outcomes:

- Understand fundamental concepts and principles of mechanics, thermal properties of materials and wave motion and sound.
- Apply physics principles to understand the causes of problems, devise strategies to solve them and test possible solutions.
- Use a range of measurement and data analysis tools to collect data … carry out analysis with due regard to uncertainties and communicate ideas and explanations.

From the outline of a customised subject for NPMs:

A student who successfully completes this unit will be able to:

- Explain and apply principles of forces, momentum and energy to the motion of objects in simple cases of relevance to the human body and applications.
- Use the concepts of physics to explain the operation of body systems such as those for breathing, circulation and metabolism.
- Determine the behaviour of simple electrical circuits, including storage and dissipation of energy in capacitor circuits, with applications such a nerve conduction and defibrillators.

As a result of considering the materials supplied, such as laboratory manuals and subject outlines, two models emerged which allow for the useful categorisation of physics subjects taught to NPMs. The identification of subjects in universities across Australia that fit each model leads naturally to the consideration of benefits/limitations that may accrue from the adoption of each model. This in turn may allow us to explore the relationships between those models and student expectations, experiences and attitudes towards physics.
Model 1
In model 1 subjects, PMs and NPMs are taught together and the subjects are prerequisites for later stage physics subjects. In some institutions, students are enrolled in first year physics and other subjects without, at that stage, being classified as majoring in any particular area and it is not until the end of the first year that it becomes clearer who are the PMs and NPMs. In such cases it may be better to describe students as intending PMs or NPMs. The syllabuses of model 1 subjects generally include topics that would be regarded as quite traditional, such as mechanics, thermal physics and electricity.

Model 2
In model 2 subjects, only NPMs are taught. We propose two sub-classifications which reflect the extent to which the subject has been designed for a specific audience.

Model 2A subjects, like Model 1, are quite conventional first year physics subjects, but are predominantly algebra-based and so are populated by NPMs only, as such subjects are not suitable prerequisites for senior physics subjects. The syllabuses of these subjects are conventional in the sense that the topics and orientation reflect a general introduction to physics with no special orientation towards other disciplines, such as engineering or the biosciences. These may reasonably be categorised as service subjects as they support the learning of students destined to major in areas other than physics.

Model 2B subjects again contain only NPMs and would not normally act as prerequisites for senior physics subjects. However, they have an intentional or overt orientation towards a particular clientele, be they majors in engineering, bioscience, or physiotherapy.

In some situations, subject descriptions may show that the subject lies somewhere between model 2A and 2B. While clear links between the physics and the major area of study of students enrolled in a subject may be absent in the subject outline (suggesting that the subject be classified as 2A) the lecturer may make significant use of examples drawn from disciplines in which the students are majoring. We therefore accept that the categorisation is imperfect. When we surveyed students taking particular subjects, we contacted the relevant subject co-ordinator (or equivalent) for advice regarding categorisation of the subject where that could not clearly established from the subject outlines.

Through a review of subject outlines available in the public domain, we were able to identify which Australian universities offered subjects aligning broadly with models 1 and 2 (see Table 1).

<table>
<thead>
<tr>
<th>Number of universities</th>
<th>Offering only model 1 subjects</th>
<th>Offering only model 2 subjects</th>
<th>Offering both model 1 and 2 subjects</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>4</td>
<td>27</td>
<td></td>
</tr>
</tbody>
</table>

Table 1: Prevalence of models 1 and 2 in Australian universities. Considering the model
We now discuss the usefulness of the models we have proposed to categorise subjects taught to NPMs. It is possible to consider approaches taken to physics teaching and learning, say at first year level, without categorising subjects by the apparent extent to which NPMs are catered for. We anticipate, however, that there are several factors that will be important to, say, student engagement with physics subjects by the way subjects are actually, or apparently, aligned to a student’s degree and career intentions/aspirations. We conjecture that a NPM student enrolled in a subject fitting models 1 and 2A, where there may be no attempt to bring special attention to the relevance of the subject to their major or align the subject with preferred graduate attributes/capabilities of the NPMs, may respond less positively to the subject than an NPM student enrolled in a subject conforming to model 2B.

In particular, it would be valuable to examine and map the relationships between subjects fitting each model to the issues described in Table 2.

<table>
<thead>
<tr>
<th>Concerning the:</th>
<th>Issues</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student</td>
<td>Expectations, retention, self efficacy and self confidence, engagement</td>
</tr>
<tr>
<td>Subject</td>
<td>Design of laboratory experiences, assessment methods, teaching approaches, links with prior knowledge/experience</td>
</tr>
<tr>
<td>Curriculum</td>
<td>Alignment with graduate capabilities/attributes, frequency of update, extent of interdisciplinary representation of curriculum development committees, frequency of updates of curricula</td>
</tr>
</tbody>
</table>

**Table 2: Matters to be considered in the context of subjects matching models 1 and 2.**

Some of these relationships are likely to be difficult to tease out (for example, the effect, if any, of any particular model on student retention) as part of a one year study. By contrast, student engagement or attitudes towards physics, for example, are likely to be easier to establish and we give this special attention in this study. As part of the project we used surveys to sample students in subjects aligning with models 1 and 2 which are representative of offerings of physics departments across a broad range of metropolitan, regional and rural universities in Australia.

Table 3 shows the categorisation of subjects (n=42) from twelve universities discussed in section 3.1 indicating the percentage of subjects falling into each category.

<table>
<thead>
<tr>
<th>Model</th>
<th>1</th>
<th>2A</th>
<th>2B</th>
<th>2A/2B?</th>
</tr>
</thead>
<tbody>
<tr>
<td>% of subjects</td>
<td>43</td>
<td>33</td>
<td>12</td>
<td>12</td>
</tr>
</tbody>
</table>

**Table 3: Categorisation of subjects conforming to models 1, 2A and 2B based on materials such as subject outlines. (The column headed 2A/2B? indicates that 12% of subjects were difficult to categorise based on available subject materials.)**
4. **What constitutes good service teaching? General**

Good practice in university teaching and learning is the main concern of many texts, papers and online articles. The latter are often found on webpages allied to ‘Centres of Learning and Teaching’ (or equivalent). Some consider university teaching and learning in general whilst others focus on first year only (see Barefoot: www.herts.ac.uk/about-us/learning-and-teaching/learning-teaching-institute/home.cfm and Krause: www.griffith.edu.au/qihe). Well established standard texts on teaching and learning (Biggs, 1991; Marton et al., 1984; Laurillard, 1993) do not attempt to draw a distinction between teaching to non-majors and teaching to majors in terms of the purpose, challenges and pressures with respect to effecting good practice.

The lack of consideration of matters impacting particularly on service teaching may represent a gap in the literature. Are there issues regarding good teaching practice which require special emphasis with respect to service teaching, that distinguishes it from non-service teaching, or are there simply differences in nuance? General propositions of good practice, for example in the area of learning from experience as expounded by Boud et al. (1993), apply to students in service subjects:

- *Experience is the foundation of, and stimulus for, learning.*
- *Learners actively construct their own experience.*
- *Learning is a holistic process.*
- *Learning is socially and culturally constructed.*
- *Learning is influenced by the socio-economic context in which it occurs.*

Issues related to engagement face learners required to enrol in a subject which they may have steadfastly avoided in the past, or which they regard as peripheral to their immediate or future needs. As Rogers commented (Rogers, 1969):

> “Nearly every student finds that large portions of his curriculum are, for him, meaningless. Thus education becomes the futile attempt to learn material which has no personal meaning.”

How well is the physics integrated into the curriculum of the major, for example to what extent do the majors a) advise on physics content/context and b) know what is being taught?

Many issues face a lecturer required to deliver a subject to students not majoring in their area of expertise. Some examples:

- *Is the lecturer comfortable when linking physics to areas in which he/she has little or no direct experience?*
- *Is the lecturer sufficiently aware of existing and emerging relationships between the physics and the students’ major?*
- *Does the lecturer perceive pressure to dumb down the physics, concerned that a poor pass rate or poor student feedback scores in a service subject may lead to its discontinuation?*

Relevance and context are key issues for students. In a recent survey canvassing students drawn from many disciplines, student motivation to learn was affected most by:
“Showing how theory can be applied in practice, establishing relevance to local cases, relating material to everyday applications, or finding applications in current newsworthy issues.”

Kember et al., 2008

The extent to which relevance is, or should be, pursued in a service subject deserves to be a matter of debate. When relevance is regarded as essential, how prepared or qualified are academics in the servicing discipline to relate more than token examples of relevance?

Turning momentarily to the bigger picture: There is growing awareness that a science degree should:

“…relate as much to the uses made of the competencies developed by graduates of the degree as to the demands of the discipline itself.”

Rodrigues et al., 2007

A physics service subject can offer important opportunities to broaden a student's vision of the scope of science, while at the same time cementing an awareness of the specific relationship between physics and their chosen major and how that relationship is likely to flourish in the future. The service subject is also able to promote the development of generic graduate capabilities which are of value irrespective of whether or not the student pursues a career in science upon graduation (Rodrigues et al. 2007).

5. What constitutes good service teaching? The academic voice

The literature is a source of guiding principles and approaches to supporting good teaching. However, the fact that such sources are generally detached from the practice of service teaching is revealed by the lack of consideration of factors impacting on service teaching. This means that it is vital to secure the insights of physics academics engaged in service teaching. To this end, and in order to establish an informed consensus with respect to good practice in service teaching, we asked physics academics with contemporary experience to consider the question “what constitutes good practice in teaching a subject designed for non-physics majors?”

25 academics from 12 universities attending an ALTC project workshop at Sydney University in September 2007 were asked to propose indicators of good practice and to distinguish, if possible, between general good practice and that which is of special relevance to service teaching. The working party leader, project officer and members of the service teaching working party subsequently reviewed the responses and ranked the indicators based on the frequency with which each was mentioned by an individual at the workshop. Approximately 75 responses were ranked. The (arbitrary) ranking scheme used is shown in Table 4.
Ranking | What the ranking means
---|---
A | >6 people mentioned this indicator
B | 2-6 people mentioned this indicator
C | 1 person mentioned this indicator

Table 4: Key to ranking of responses on indicators of good practice.

The outcome of the ranking process is shown in table 5.

<table>
<thead>
<tr>
<th>Good Practice</th>
<th>General (i.e. applicable to all)</th>
<th>Rank</th>
<th>More specific emphasis for NPMs</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Builds on students’ experience</td>
<td>A</td>
<td>Context/site of application of the physics has meaning for the student</td>
<td>A</td>
<td></td>
</tr>
<tr>
<td>Curriculum not overloaded</td>
<td>B</td>
<td>Recognises the future use to which students may apply the principles learned</td>
<td>A</td>
<td></td>
</tr>
<tr>
<td>Aims &amp; goals clearly stated</td>
<td>B</td>
<td>Contexts employed have explicit relationships with the major area</td>
<td>A</td>
<td></td>
</tr>
<tr>
<td>Offers challenges to students (whether students are above or below average)</td>
<td>B</td>
<td>Students are made aware of the role that physics has played/plays in the development of their major area of study</td>
<td>B</td>
<td></td>
</tr>
<tr>
<td>Theory and practice of physics clearly linked</td>
<td>C</td>
<td>Specific elements (e.g. the laboratory program) are set in contexts which have a bias or flavour derived from the NPMs’ discipline area(s)</td>
<td>B</td>
<td></td>
</tr>
<tr>
<td>Students at risk identified early and supported</td>
<td>C</td>
<td>Curriculum developed is updated by a group containing representatives from the NPMs’ discipline area(s)</td>
<td>C</td>
<td></td>
</tr>
<tr>
<td>Provides timely, individualised feedback to students</td>
<td>C</td>
<td>Aims and goals clearly relate to graduate attributes articulated by NPMs’ discipline area(s)</td>
<td>C</td>
<td></td>
</tr>
<tr>
<td>Improves student self-confidence</td>
<td>C</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 5: Ranked indicators of good practice in physics teaching.

We remark that the indicators given an ‘A’ ranking in Table 5 align well with those mentioned in the literature (see, for example, Kember et al., 2008).

‘Context/site of application of the physics has meaning for the student’ ranks highly amongst the responses of the lecturers attending the workshop. Evidence from other sources would suggest that many academics, even within the serviced disciplines, would support the notion that physics should be learned for its own sake, i.e. without any special emphasis on applications to the student major (Kirkup et al. 1998). We speculate that, as most academics taking part in the workshop had a special interest in service teaching, their views may not be representative of the physics teaching community as a whole with regard to their emphasis on the importance of the applications of physics.
6. What constitutes good service teaching? The student voice

Inspired by the top three ranking indicators of good practice in service teaching shown in Table 5, we devised two student surveys. The first included questions aimed at revealing student expectations of the subject with regard to links being made between physics and their chosen (or intended) major. The second survey was designed to reveal whether their experiences of the subject, over the course of the semester in which they were enrolled in the subject, matched their expectations.

Through surveying students we wished to establish the impact of a single semester of physics on students destined to major in disciplines other than physics. A prototype survey was devised and trialled to uncover expectations and experiences of non-physics majors enrolled in a first year physics subject. In order to assist the development of the survey, we trialled the surveys on bio/medical science majors at a large metropolitan university. We wished to:

- explore student views of the value of physics to their major area of study,
- determine whether those views were transformed over the course of the semester,
- examine themes relating to service teaching which might provide direction for a larger survey and have relevance on a national level,
- establish the extent to which students expected links to be made between the physics they studied and the discipline in which they were (or were likely to be) majoring,
- provide points of comparison, for example on laboratory experiences, with the same surveys administered nationally,
- revise the survey questions (if appropriate) in the light of student responses (for example, in order to improve the clarity of the questions).

Survey A (expectations) was designed to be administered at the beginning of semester and survey B (experiences) at the end of the semester, but before the start of the examination period. The surveys were deliberately brief as students are faced with a plethora of surveys every semester and survey fatigue is a frequent and legitimate complaint among students. Survey A examines students attitudes towards physics and expectations of the subject they are about to commence. Survey B consists of identical, or complementary, questions. After trialling the survey and seeking advice from a teaching and learning specialist, some questions were revised (questions 2, 4, 6 and 7). The revised questions formed part of a larger survey which was administered to 22 Australian universities (see Section 7).

Several questions were designed to draw out whether students expect the relevance of physics to their major area of study to be manifest and whether, having reached the end of the subject, that expectation was realised (see questions 1, 3, and 9). Other questions aimed to uncover student general attitudes towards physics and the study of physics (questions 2, 4, 8 and 10). In such a short survey we did not wish to cover too much ground, but as mathematics is so important to the study of physics, and laboratories (at least in terms of time) are major contributors to the first year experience in physics, we included questions on each of these (questions 5 and 7 respectively).
<table>
<thead>
<tr>
<th></th>
<th>Survey A</th>
<th>Survey B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q1</td>
<td>It is apparent to me that this subject is a valuable part of my degree.</td>
<td>It is apparent to me that this subject is a valuable part of my degree.</td>
</tr>
<tr>
<td>Q2</td>
<td>Only unusually able people are capable of understanding physical principles in science. (Only people with an extraordinary ability are capable of understanding physics).</td>
<td>Only unusually able people are capable of understanding physical principles in science. (Only people with an extraordinary ability are capable of understanding physics).</td>
</tr>
<tr>
<td>Q3</td>
<td>I am keen to see how this subject links to my major area of study.</td>
<td>I am able to appreciate the links between this subject and my major area of study.</td>
</tr>
<tr>
<td>Q4</td>
<td>I am anxious about studying this subject this semester (I believe an understanding of physics will benefit my studies in other areas of my degree).</td>
<td>I am anxious about my upcoming exam in this subject. (I believe an understanding of physics will benefit my studies in other areas of my degree).</td>
</tr>
<tr>
<td>Q5</td>
<td>I am confident that my mathematics background is sufficient for me to be successful in this subject.</td>
<td>I believe my mathematics background was sufficient for me to be successful in this subject.</td>
</tr>
<tr>
<td>Q6</td>
<td>If offered, I would take advantage of extra maths support that was directly related to the maths in this subject. (I expect to do well in class tests in this subject).</td>
<td>My achievements in class tests in this subject exceeded my expectations.</td>
</tr>
<tr>
<td>Q7</td>
<td>I am looking forward to doing labs in this subject.</td>
<td>I enjoyed the labs in this subject. (The labs in this subject were a positive learning experience).</td>
</tr>
<tr>
<td>Q8</td>
<td>If it were possible, I would have avoided taking this subject.</td>
<td>I would advise others to avoid taking this subject if at all possible.</td>
</tr>
<tr>
<td>Q9</td>
<td>I expect the links between this subject and my major area of study to be made obvious throughout the semester.</td>
<td>The lecturers succeeded in linking this subject to my major area of study.</td>
</tr>
<tr>
<td>Q10</td>
<td>I expect to have to work harder in this subject than in my other subjects this semester.</td>
<td>I worked harder in this subject than for my other subjects this semester.</td>
</tr>
<tr>
<td>Q11</td>
<td>What final grade are you aiming for in this subject?</td>
<td>What final grade are you aiming for in this subject?</td>
</tr>
<tr>
<td>Q12</td>
<td>Did you study physics to year 12 at school?</td>
<td>Did you study physics to year 12 at school?</td>
</tr>
<tr>
<td>Q13</td>
<td>Open-ended question: Please describe briefly any particular expectations you have as you begin your study in this subject.</td>
<td>Open-ended question: Please describe briefly your experience of this subject, and in particular what you think might be done to improve the subject.</td>
</tr>
</tbody>
</table>

Table 6: Survey A (expectations) and Survey B (experiences) questions.

The revised versions of the questions (used in the national survey) are parenthesised and shaded.
Questions 1 to 10 use the standard 5-point Likert scale, where the multiple-choice responses range from strongly disagree to strongly agree, with neutral in the centre. Question 11 is also multiple-choice, the response categories are: don’t know, pass, credit, distinction and high distinction.

The physics subject chosen for the trial was populated wholly by NPMs drawn from the biological/medical sciences, half of whom had not completed year 12 physics. The subject consists of 3.5 hours of lectures/tutorial and 2.5 hours of laboratory time each week. The laboratory and lecture material were in-step and all the students did the same experiment at the same time. About 150 responses were obtained for each of surveys A and B, representing a response rate of 85 to 90%.

After assigning a number to each of the response categories on the Likert scale (strongly disagree = 1, disagree = 2, neutral = 3, agree = 4 and strongly agree = 5), the mean expectations scores (survey A) and experiences scores (survey B) were calculated for each of the first ten multiple-choice survey questions. The majority of questions were worded in such a way that higher scores correlated with positive expectations (or experiences) of the subject. Questions 2 and 8 were exceptions to the rule, as good expectations (or experiences) of the subject would be anticipated to elicit negative responses.

The mean expectations score was subtracted from the mean experiences score on matched questions in surveys A and B. A positive difference indicates that the students’ experiences exceeded their expectations and a negative difference indicates the converse; a value close to zero suggests that experiences closely matched expectations. In order to be able to rank questions 2 and 8 on the same scale, the process was reversed with the experiences score subtracted from the expectations score. Questions 4 and 6 were omitted from this analysis as the links between corresponding questions in surveys A and B in the original version of the questionnaire were absent or tenuous. Figure 1 shows the questions ranked in order of change.
2.80  2.78  2.22  2.30  2.95  3.25  3.48  3.64  3.73

Figure 1: Mean expectations (survey A) and experiences (survey B) scores for the 2007 trial survey responses ranked by the differences. Note that calculation of the Q2 and Q8 differences are reversed (explanation in text).

In order to establish whether any of the differences were statistically significant a t-test was performed on each. A two-tailed, two sample equal variance distribution was used in performing the t-test. The results are presented in Table 7. The t-test revealed that the large differences associated with questions 3, 5, 7 and 10 are statistically significant (p < 0.05).

<table>
<thead>
<tr>
<th></th>
<th>Q1</th>
<th>Q2</th>
<th>Q3</th>
<th>Q5</th>
<th>Q7</th>
<th>Q8</th>
<th>Q9</th>
<th>Q10</th>
</tr>
</thead>
<tbody>
<tr>
<td>p</td>
<td>0.58</td>
<td>0.88</td>
<td>&lt;0.05</td>
<td>&lt;0.05</td>
<td>&lt;0.05</td>
<td>0.23</td>
<td>0.37</td>
<td>&lt;0.05</td>
</tr>
</tbody>
</table>

Table 7: Statistical analysis of differences between expectations and experiences means (for individual survey questions).

Questions 1, 2, 8 and 9 showed no statistically significant difference between surveys A and B, denoting that experiences were closely matched to expectations. In general, non-significant differences are worthy of consideration. For example, a low score on corresponding questions in surveys A and B would be a matter requiring exploration, i.e. absolute values for responses may be as important as, or more important than, changes that occur over a semester.

Question 5, “I am confident that my mathematics background is sufficient for me to be successful in this subject”, was the only one for which experiences significantly exceeded expectations. The responses at the beginning of semester suggested students were unsure of this statement (indicated by a mean score of 3.37 which is close to the neutral value of 3) but by the end of semester they were much closer (mean of 3.73) to agreeing with the statement. We conjecture that students were concerned that a physics subject would require an amount of fluency with mathematics that they did not possess, but that experience of the subject showed them that their mathematical abilities were adequate for the purposes of satisfying the requirements of the subject.
The three questions in which experiences were significantly less than expectations were question 3 (seeing clear links), question 7 (enjoying the laboratory) and question 10 (work harder than in other subjects). Question 10 is useful for gauging student perceptions of the effort expended in this subject relative to other subjects s/he is taking but is not a question in which a preferred direction of response can be unequivocally stated. The other two questions can shed some light on areas requiring further examination. In particular, the responses concerning the laboratory suggest that a review of the laboratory program or its implementation be considered. Students went from feeling neutral about the laboratory component at the start of semester (mean of 3.10) to rather negative about it by the end (mean of 2.59).

The last question on surveys A and B was open-ended and sought to qualitatively probe the expectations and experiences, respectively, of students taking the subject. About half the survey participants responded to this question. The most common expectations and experiences that emerged are given in Table 8.

<table>
<thead>
<tr>
<th>Expectations</th>
<th>Experiences</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. The subject should be made interesting. (6)</td>
<td>1. Concerns relating to the provision of laboratory experiences. (22)</td>
</tr>
<tr>
<td>2. The subject will be challenging/difficult. (6)</td>
<td>2. The lectures/lecturers were interesting. (15)</td>
</tr>
<tr>
<td>3. Shouldn’t have to stay until end of lab session as already have a full timetable. (6)</td>
<td>3. Should provide more worked examples as well as working solutions to the resource book. (8)</td>
</tr>
<tr>
<td>4. Should be able to see links with major area of study. (5)</td>
<td>4. There were a number of class tests issues. (7)</td>
</tr>
<tr>
<td>5. The subject will require a lot of maths and calculations. (5)</td>
<td>5. The subject was challenging and difficult. (4)</td>
</tr>
<tr>
<td>6. I will learn new things. (5)</td>
<td>6. There should be more links made between labs to lectures and/or theory. (3)</td>
</tr>
</tbody>
</table>

Table 8: Dominant student expectations and experiences. Number in brackets denotes number of student responses.

The open-ended responses support a number of the observations that emerged in the mean score differences shown in Figure 1. The experiences section affirms student frustration with the laboratory component of the subject. Moreover it provides useful information, detailing student concerns with the design and implementation of the laboratory program:

“Better lab sessions i.e. more interesting experiments, better lab tutors.”

“Improve the labs, making them more interesting, with better explanations from tutors rather than the vague and confusing explanations that were often given.”

More encouragingly, the second most popular response category (in the experiences section) details a positive attitude towards both the lectures and the lecturers.
“X and Y’s lectures were very interesting, especially when demonstrations were carried out.”

“The lectures given were very interesting and involving for the students, X did very well in explaining concepts and the way he taught (writing notes on the projector during lectures was great).”

Surveys A and B were designed specifically for matters relating to students not majoring in physics in mind. The survey was valuable in teasing out areas of particular concern. In the trial of the surveys it was apparent that students were neutral or positively disposed toward laboratories on entering the subject, but that their experiences fell short of their expectations. The open-ended responses gave substance to the issues of most concern and form the basis of detailed considerations.

As a result of the surveys the laboratory program for this subject has undergone significant revision.

The trial of the surveys suggested that they have the potential for uncovering national themes. For example, a question prompted by the preliminary study is “to what extent are laboratories physics experiences for non-physics majors a national issue?” In order to answer this question and explore student views relating to service teaching on a national scale (such as the importance of linking physics to their major area of study), we contacted university physics departments across Australia to seek their participation in a nationwide survey.

### 7. Expanding expectations/experiences surveys to 35 subjects from 22 universities

Service teaching working party members, numerous HODs and teaching academics in physics departments across Australia were pivotal in expanding the reach of the expectations/experiences surveys. We surveyed students enrolled in 35 subjects taught to non-physics majors in 22 Australian universities spanning the Australian Capital Territory, New South Wales, Queensland, South Australia, Victoria and Western Australia. Over 7500 completed surveys were returned for analysis. The surveys were carried out at the beginning and end of the autumn semester 2008. There was good representation from GO8, ATN, as well as rural and regional universities. Table 9 lists all 22 participating universities.

<table>
<thead>
<tr>
<th>Adelaide</th>
<th>ADFA@UNSW</th>
<th>ANU</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central Queensland</td>
<td>Curtin</td>
<td>Edith Cowan</td>
</tr>
<tr>
<td>Flinders</td>
<td>La Trobe</td>
<td>Murdoch</td>
</tr>
<tr>
<td>New England</td>
<td>Newcastle</td>
<td>New South Wales</td>
</tr>
<tr>
<td>Queensland</td>
<td>QUT</td>
<td>RMIT</td>
</tr>
<tr>
<td>South Australia</td>
<td>Swinburne</td>
<td>Sydney</td>
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<tr>
<td>UTS</td>
<td>Victoria</td>
<td>Western Australia</td>
</tr>
<tr>
<td>Western Sydney</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Table 9: Universities participating in the national expectations/experiences surveys.**
**Administering surveys**

The questions comprising surveys A and B are given in Table 6. Survey A, designed to examine student expectations, was administered to students in week 1 or 2 of autumn semester 2008. Survey B, which considered student experiences, was administered at the end of the semester but before the formal examination period. The contact person at each physics department was responsible for co-ordinating the time and place for administering the survey, collecting the completed surveys and returning them to the project officer for analysis. The option of keeping copies of the completed surveys (for personal analysis) was available to each department, however the project team was responsible for analysing the complete data set. Once this analysis was completed, departments were sent a copy of their individual results. A selection of the overall results was made available on the project website ([www.physics.usyd.edu.au/super/ALTC](http://www.physics.usyd.edu.au/super/ALTC)), with any information leading to the identification of departments or individuals removed.

Surveys were prepared in computer scan-able format to facilitate the data management process. The Quality Unit (PQU) at UTS was responsible scanning 4414 Survey A and 3109 Survey B responses and embedding the data in Excel spreadsheets, which were then handed over to the project officer.

Subsequent data analysis was carried out in the Excel spreadsheets. The analysis was chiefly statistical, with the main component involving averaging the quantitative multiple-choice questions. Mean values for individual questions were thus obtained, both for the overall data set and for each of the 35 subjects. A parameter for each subject was proposed, the *index of change* (IOC), which is a measure of how well students’ experiences matched their expectations (see Section 7.4).

**Majors participating in survey**

Students completing the surveys were asked to declare their majors. While recognising that some students may not accurately relay their major, we believe that Table 10 (over) gives a fair representation of the diversity of NPMs that routinely enrol in first year physics subjects across Australia.
<table>
<thead>
<tr>
<th>SCIENCE</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Anatomy</td>
<td>Animal Science</td>
<td>Archaeology</td>
</tr>
<tr>
<td>Astronomy</td>
<td>Astrophysics</td>
<td>Biochemistry</td>
</tr>
<tr>
<td>Biological Science</td>
<td>Biology</td>
<td>Biomedical Science</td>
</tr>
<tr>
<td>Biophysics</td>
<td>Biotechnology</td>
<td>Cell Biology</td>
</tr>
<tr>
<td>Chemistry</td>
<td>Computer Science</td>
<td>Conservation Biology</td>
</tr>
<tr>
<td>Earth Science</td>
<td>Ecochemistry</td>
<td>Environmental Science</td>
</tr>
<tr>
<td>Environmental Chemistry</td>
<td>Ecological Science</td>
<td>Ecology, Behaviour and Evolution</td>
</tr>
<tr>
<td>Evolutionary Biology</td>
<td>Food Science</td>
<td>Forensic Investigations</td>
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<tr>
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<td>General Science</td>
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<td>Health Science</td>
<td>Human Biology</td>
<td>Human Movement</td>
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<td>Industrial Chemistry</td>
<td>Life Sciences</td>
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<td>Marine Science</td>
<td>Material Science</td>
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<td>Medical Biochemistry</td>
<td>Medical Imaging Science</td>
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<td>Medical Microbiology</td>
<td>Medical Radiation Science</td>
<td>Medical Science</td>
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<td>Microbiology</td>
<td>Molecular Biology</td>
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<td>Nanotechnology</td>
<td>Nanoscience</td>
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<tr>
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<td>Nutrition</td>
<td>Occupational Health and Safety</td>
</tr>
<tr>
<td>Ocean and Climate Science</td>
<td>Oceanography</td>
<td>Oenology</td>
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<tr>
<td>Optometry</td>
<td>Pathology</td>
<td>Pharmacology</td>
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<tr>
<td>Physical Sciences</td>
<td>Physiology</td>
<td>Physiotherapy</td>
</tr>
<tr>
<td>Psychology</td>
<td>Radiation Science</td>
<td>Radiology</td>
</tr>
<tr>
<td>Resource and Environmental Science</td>
<td>Sports Medicine</td>
<td>Sports Science</td>
</tr>
<tr>
<td>Statistics</td>
<td>Viticulture</td>
<td>Zoology</td>
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<tr>
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<td>Computer</td>
<td>Construction</td>
<td>Design</td>
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<td>Software</td>
<td>Telecommunications</td>
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<table>
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<tr>
<td>Accounting</td>
<td>Actuarial Studies</td>
<td>Air Transportation Management</td>
</tr>
<tr>
<td>Architecture</td>
<td>Arts</td>
<td>Aviation</td>
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<tr>
<td>Business</td>
<td>Business Management</td>
<td>Chiropractic</td>
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<tr>
<td>Commerce</td>
<td>Education</td>
<td>Finance</td>
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<tr>
<td>Graphic Design</td>
<td>ICT (Computer Systems)</td>
<td>ICT (Software)</td>
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<td>Major</td>
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<tr>
<td>ICT (Telecomm)</td>
<td>IT</td>
<td>Japanese</td>
</tr>
<tr>
<td>Law</td>
<td>Marketing</td>
<td>Medicine</td>
</tr>
<tr>
<td>Medicine and Neuroscience</td>
<td>Medicine and Surgery</td>
<td>Naval Architecture</td>
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<tr>
<td>Physical Education</td>
<td>Security Management</td>
<td>Surveying</td>
</tr>
</tbody>
</table>

Table 10: Range of majors surveyed.
Overall data set

As explained in Section 6.2, the mean expectations score was subtracted from the mean experiences score, for each question. A positive difference indicates that students’ experiences exceeded their expectations for that question, and a negative difference indicates the converse. Figure 2 shows the consolidated data for all responses with questions ranked in order of positive to negative change.

The answers to the questions in the experiences survey were consistently biased towards less favourable responses when compared to the matching questions in the expectations survey. t-tests revealed that all questions except question 5 (where there was no change between expectation and experience scores) show statistically significant differences. Emphasising the main features shown in Figure 2:

- The mean scores relating to questions on links with major (1, 3 and 9), value to other areas of their degree (4), and laboratories (7) as obtained in the experiences survey were significantly less than the mean scores of the corresponding questions in the expectations survey.
- The mean scores for question 6 in the experiences survey indicates that students on average performed less well in their class tests than they had expected to.
- The mean scores for question 8 for the expectations/experiences surveys indicates a bias towards advising others to avoid the subject. (But note that in both the expectations and experiences surveys, the mean score is less than the neutral score of 3.)
- The change in the mean score for question 2 (“Only people with an extraordinary ability are capable of understanding physics”) suggests that more students came to believe this over the course of the semester. (But note that in both the expectations and experiences surveys, the mean score is less than the neutral score of 3.)
Figure 2: Aggregated data for all subjects surveyed showing the mean response to each multiple-choice question in surveys A and B. The questions are ranked according to how well the experiences matched the expectations (the change is shown graphically on the RHS).

Aggregating the data causes variation on a local scale to be obscured. In order to investigate trends at the local level we collapsed the overall data set and looked at the differences in expectations/experiences for each subject (see Figure 3 for each question’s corresponding plots).
Q2. Only people with an extraordinary ability are capable of understanding physics.

Q3. There are clear links between this subject and my major area of study.

Q4. I believe an understanding of physics will benefit my studies in other areas of my degree.

Q5. I am confident that my mathematics background is sufficient for me to be successful in this subject.
Q6. My achievements in class tests in this subject exceeded my expectations.

Q7. The labs in this subject were a positive learning experience.

Q8. I would advise others to avoid taking this subject if at all possible.

Q9. The lecturers succeeded in linking this subject to my major area of study.
Figure 3: Difference (experience – expectation) scores for each question, by subject. A positive difference (bar above the axis) indicates that experiences exceeded expectations.

[Note that, due to circumstances beyond our control, three subjects did not participate in survey B.]

Four of the questions (1, 4, 6 and 9) performed only moderately across the board, with few if any subjects able to sustain the expectations at the start of the semester. This is of concern as three of the four questions deal with the links and worth of the subject to the major/degree.

7.4 Index of change (IOC)

In order to create an indicator that captures the change that occurs between student expectations and experiences for each subject, and which combines the responses to the questions where there is a preferred direction in the responses, we propose an index of change (IOC). The IOC is defined as the mean of all the questions’ (experience – expectation) scores. An individual IOC value is calculated for each subject.

Two points to note:
1. Question 10 “I worked harder than in other subjects” is not included in the calculation of IOC as there is no clear-cut preference (from our point of view) for either a positive or negative change.
2. In questions 2 and 8 the experiences score was subtracted from the expectations score as a good experience of a subject would be anticipated to elicit negative responses for these questions.

An IOC was calculated for each of the 32 subjects (three subjects did not complete Survey B). Of these, one subject produced a positive IOC. Thus, almost all subjects produced a negative IOC. We used t-tests to determine whether the overall measure of change between student expectations and experiences was statistically significant. 23 subjects were found to have significantly declined, with 9 subjects displaying no significant change (see Figure 4).
One of the areas of interest to the project involved determining whether the different subject model types afford different experiences to students. To this end we grouped all 35 subjects into one of the three models (1, 2A and 2B) and re-plotted the \( IOC \) data shown in Figure 4. Table 11 details the breakdown of the 35 subjects and Figure 5 shows the \( IOC \) data grouped by model.

Table 11: Categorisation of subjects conforming to models 1, 2A and 2B. The three subjects marked with an * did not complete Survey B.
Figure 5: Index of change, \( IOC \), for 32 subjects surveyed. The Model 1 subjects are grouped together on the LHS, the Model 2A subjects in the middle and the Model 2B subjects on the RHS. Each model grouping is ordered according to the \( IOC \).

A chi-squared test indicates the probability of the observed distribution of significant \( IOC \) values in Figure 5 is 0.12, and is therefore not statistically significant. Despite the lack of statistical significance we believe that the relationship between the subject model and the \( IOC \) is sufficiently interesting to warrant further investigation.

An open-ended question was included which asked students to describe any particular expectations they had (survey A) or overall experiences (survey B). The responses were sorted into a number of categories that emerged as the analysis took place. A number of open-ended responses were not able to be classified due to a variety of reasons (including being very specific, unintelligible, derogatory, silly, etc).

For Survey A, there were 1681 open-ended responses (total \( n = 4414 \)) to the statement “please describe briefly any particular expectations you have as you begin your study in this subject”, which represents a response rate of 38%. The major categories the responses can be placed in were:

- want to learn, better understand physics
- think physics is difficult
- think physics is interesting, fun
- continuation, consolidation of high school physics
- want to see links to major, degree
- expectations regarding labs, experimental work
- expectations of lots of examples, practice problems, tutorials
- concerns about passing
The breakdown of responses by category is shown in Figure 6. A significant proportion of incoming students appear keen to study physics. Over a quarter of all students answering this question were interested in learning and or better comprehending physics. Although one-sixth of these students feel that physics is difficult, one-tenth think physics is interesting. 6% of responses mention wanting to see links with the major and expectations concerning the laboratory work.

Categories derived from the open-ended responses to survey B were:
- want more examples, practice problems, tutorials
- NEGATIVE comments concerning labs, experimental work
- think physics is too difficult
- think physics is interesting, fun
- NEGATIVE comments concerning teaching staff
- NOT a good learning experience
- a good learning experience
- POSITIVE comments concerning labs, experimental work
- NEGATIVE comments concerning links to major, degree
- POSITIVE comments concerning teaching staff
- physics was NOT interesting, fun, enjoyable
- maths involved too difficult
- need extra assistance from staff
- large (NEGATIVE) jump from high school physics

Figure 6: Survey A open-ended response categories.
A higher percentage of students answered this question, with 1817 responses (total n = 3109), a response rate of 58%. The breakdown of responses by category is graphically shown in Figure 7.

The biggest request is that more examples and practice problems be given. Not surprisingly students are keen to secure all the help they can to pass the subject. The laboratory component is heavily biased towards negative comments as are the links made to the major and degree. This is now explored in more detail.

Survey B open-ended responses indicate that linking the subject with the major and laboratory work are issues deserving further attention. This aligns with the findings of the earlier study used to trial the questions (see section 6.2). As these are issues that were also addressed in the multiple-choice questions, we draw attention to them and bring together related student perceptions. We present (in Figure 8) revised versions of the graphs seen in section 7.5, showing the percentage of open-ended responses both issues received.
LABS and LINKS
SURVEY B
(total comments = 1817)

Figure 8: Percentage of open-ended responses commenting on *links to major* and *laboratories*.

Figure 9 shows a breakdown of the negative responses to the labs. The key messages are:

- improve the links between the laboratories and the lectures
- revise the laboratory notes
- review the support given in the laboratories by the revitalise the laboratories to make them more appealing

Figure 9: Breakdown of open-ended responses commenting negatively on *laboratories*.

Well performing subjects regarding links to major
The subset of multiple-choice questions which deal with student perceptions of the relevance and value of the subject as it relates to their major and/or degree is shown in Table 12.

<table>
<thead>
<tr>
<th>Survey A</th>
<th>Survey B</th>
</tr>
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<tbody>
<tr>
<td>Q1</td>
<td>It is apparent to me that this subject is a valuable part of my degree.</td>
</tr>
<tr>
<td>Q3</td>
<td>I am keen to see how this subject links to my major area of study.</td>
</tr>
<tr>
<td>Q9</td>
<td>I expect the links between this subject and my major area of study to be made obvious throughout the semester.</td>
</tr>
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Table 12: The subset of survey A (expectations) and survey B (experiences) questions dealing with the links between physics and the students’ major area of study.

The survey A and B responses to questions 1, 3 and 9 were summed for each subject. Using the Likert scale, if all students awarded the highest score (5) to all three questions, then that subject would have a cumulative score of 15. By contrast, if all students awarded the lowest score (1) to all three questions, then that subject's cumulative score would be 3. Figure 10 shows the score for all subjects completing surveys A and B.

Figure 10: Combined scores for questions 1, 3 and 9 for both surveys A and B for all subjects.

With a few exceptions the expectations scores were quite high, with an average value between 11 and 12. The experiences scores, however, did not match expectations for the three questions under consideration. Closer inspection indicates that some subjects (notably 5, 16 and 20) show high expectations scores which are matched by high experiences scores. Other subjects (notably 7, 10, 12 and 29) show a substantial decline from expectations to experiences scores. Although
subject 7 showed a substantial fall in its mean score, there were only six responses to survey B for this subject, making any conclusions tentative at best.

We now look more closely at those subjects that underwent the least and most change. Figures 11 and 12 respectively show the frequency of the open-ended comments made by students in the least change subjects (5, 16 and 20) and those in the most change subjects (10, 12 and 29). The students in the least change subjects made only one negative comment with respect to links to the majors (out of 148 total comments), but at the same made only three positive comments. By contrast, there were 19 negative comments (out of 169 total comments) in the most change subjects and not a single student commented positively about the links. These findings from the open-ended response questions are consistent with the findings from the multiple-choice questions concerning the links (1, 3 and 9).

<table>
<thead>
<tr>
<th>Subject</th>
<th>Comments</th>
</tr>
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<tbody>
<tr>
<td>5</td>
<td>1 (negative)</td>
</tr>
<tr>
<td>16</td>
<td>3 (positive)</td>
</tr>
<tr>
<td>20</td>
<td>1 (negative)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Subject</th>
<th>Comments</th>
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<tbody>
<tr>
<td>10</td>
<td>19 (negative)</td>
</tr>
<tr>
<td>12</td>
<td>1 (positive)</td>
</tr>
<tr>
<td>29</td>
<td>0 (positive)</td>
</tr>
</tbody>
</table>

**Figure 11**: Frequency of comments made by students enrolled in subjects that showed least change between the expectations and experiences as revealed by the analysis of questions 1, 3 and 9.
If we compare the frequency of negative comments relating to laboratory experiences, we find there is little difference between those subjects showing least change, with 14 negative comments (out of 148 total comments, equal to 9.5%), and those subjects that showed most change, which accumulated 20 negative comments (out of 169 total comments, equal to 12%). This finding points to the physics laboratory experience, for students not majoring in physics, as being an issue even in those subjects that have otherwise been viewed positively by students in the way in which the subject related physics to their major area of study.

7.8 Acting on results: the academics’ perspective

To bring substance and specificity to the consideration of the features of service subjects that succeeded in marryng high experience scores with high expectations scores, we asked the co-ordinators of subjects 5, 16 and 20 (who we now identify) to give an overview of each of their subjects. We also requested they reflect on what facets of the subject may have facilitated the positive student response. We present below unedited versions of their reflections which also contain details of subject content, descriptions of the student cohort and assessment information.
Physics for Medical Radiation (University of South Australia) – MODEL 2B subject

Co-ordinator - Nick Mermelengas

Introduction
Medical radiation technologists have been trained at the University of South Australia and its predecessors, since the 1970s. A new four year Bachelor of Medical Radiation Science began this year with streams in Medical Imaging, Nuclear Medicine and Radiation Therapy. The new program includes four “Physics for Medical Radiation” courses, two each in the first and second years.

Unit content
The two first-year, algebra-based courses, were specifically designed to introduce the physics knowledge and understanding required by radiation technologists. The content includes basic mechanics, electricity and magnetism, atomic physics, electronics, the physics of medical imaging and radiation therapy. The courses are presented as follows: two lectures and one tutorial session per week plus one two-hour laboratory session per fortnight. The first semester laboratory sessions cover electrical basics and radioactivity and the second semester sessions cover the physics of X-rays.

Assessment
Assessment consists of six fortnightly quizzes worth 20%, six fortnightly laboratory reports worth 20% and a final examination worth 60%. A weekly set of exercises, consisting of formative conceptual questions and numerical problems, is discussed in the tutorials.

Student cohort
The Tertiary Entrance Rank for the Bachelor of Medical Radiation Science was in the mid-nineties. Physics is not listed as either a prerequisite or as assumed knowledge. Consequently, of the 89 students enrolled, only 29% had completed year 12 physics. In general terms, the student cohort is a highly motivated and high-achieving group with an impressive work ethic. Despite many students expressing a concern about their lack of physics background, the final results in semester one were excellent with an average mark of 76%.

Results of the survey
The students enrolled in “Physics for Medical Radiation 1” completed a survey at the beginning (Expectations) and end (Experiences) of semester one, as part of the Service Teaching strand of the project “Forging New Directions in Physics Education in Australian Universities”. On the basis of these surveys, the course was ranked in the top three out of 35 in the area of the relevance and links between physics and the students' major area of study.

Comments and conclusion
The primary reason this course was ranked highly by the students themselves, I believe, is the fact that the course was deliberately designed from the beginning to provide the physics knowledge required by radiation technologists. A typical student comment was: “information taught related directly to our profession, similarly the practicals”. Other reasons include a simple and well-organised course structure and assessment structure: “having quizzes every two weeks meant we were able to stay on top of our workload”, as well as the use of an excellent textbook (Physics of Radiology by A. B. Wolbarst). Finally, the nature of
the student group itself was an important factor. In general, they are an intelligent, hard-working and pleasant group of people and they were a pleasure to teach. On a lighter note, I was amused to read the following student comment “Nick is wicked!” However, shortly after, I came across the following comment: “Our prac teacher, Richard, is awesome”. The question arises; does “wicked” or “awesome” win bragging rights?

Physics and Materials (University of Western Sydney) – MODEL 2A subject

Co-ordinator - Ragbir Bhathal

Introduction
Physics & Materials is a first year unit for engineering students at the University of Western Sydney (UWS). It is taught only in the first semester in the first year of a four year engineering degree. It is a compulsory unit for all students studying various engineering disciplines (electrical, civil, telecommunications, environmental, computer, robotics and mechatronics) at UWS. It is also a requirement by Engineers Australia that the students do at least one semester of physics in their engineering course. Physics is seen as a fundamental subject for engineering studies.

Engineering applications
Unlike pure physics students who are usually satisfied with "physics for physics sake" phenomena and explanations, I find that engineering students want to know the practical engineering applications of physics that is taught to them. They also need to be convinced of the relevance of physics to their engineering studies. This is quite different to the attitude of physics majors who are studying physics. Hence, at various and appropriate points in the lectures it is essential to provide the students examples of how the principles and theories of physics which they are taught in the lectures are used in real life engineering situations. For example, when we are studying the mathematical formulation of waves and wave phenomena students are informed how the study of waves has applications in the building of bridges, and the acoustics of concert halls. They are also given illustrations of how the wave equation is used in the study of the properties and propagation of electromagnetic waves, how wave phenomena are used in telecommunications, the construction of telescopes and the study of the atomic structure of matter. A practical on standing waves is used to illustrate the nature and properties of waves and wave phenomena. The students find the visual representation of the mathematical formulation of waves in the practical exercise extremely useful for their understanding of the nature and properties of waves.

Historical aspects
In the course of delivering the lectures I also briefly discuss at appropriate points in the lectures the historical aspects of the development of concepts and theories in physics. This gives students an insight into how creative physicists and engineers formulate and arrive at concepts and theories to understand a phenomenon or solve a technical problem. I also provide snippets of some of the interesting aspects of the lives and personalities of physicists, such as Galileo and the Inquisition, Newton’s apple and the discovery of the laws of motion, the Bernouli family and fluid mechanics, etc. Students appreciate these little bits of information and these asides enhance and make the lecture much more interesting and lively. I have also found that a little bit of humour helps to liven up the lecture and gets students’ attention.
Practicals
In general, the reasons for doing the practicals in the first year engineering physics unit can be grouped under three broad headings: cognitive (improving students’ understanding of physics and testing whether the theory works), affective (practicals are interesting and exciting and help promote positive attitudes towards physics and engineering) and skills (developing skills to manipulate equipment, observing and measuring; learning processes such as predicting, inferring and evaluating; working as a member of a team and understanding of scientific enquiry). The practicals have been found to be useful tools for reinforcing the understanding of the concepts and theories which are taught in the lectures. They have also provided the students with the skills of planning and executing the experiment to obtain measurements and observations with which they can test the predictions from the theories. In the process they learn the scientific method, one of the most powerful means of validating the theoretical foundations of physics.

Learning outcomes
At the completion of this unit, it is expected that students will be able to:

- Explain the basic principles of physics and their applications in engineering.
- Analyse and solve numerical problems relating to physical systems.
- Plan, conduct and document experiments performed in the laboratory.
- Interpret the results of experiments against the theory including the estimation of experimental uncertainties and carry out dimensional analysis.

Unit content
The unit is calculus based and students are expected to have done at least HSC mathematics with calculus. The topics include units and dimensional analysis, linear, circular and rotational motion, applications of Newton’s laws, conservation laws, wave phenomena, electricity and magnetism, atomic and nuclear structure, geometrical and physical optics, molecular structure and condensed matter, thermal properties of matter, fluid mechanics, degradation and sustainability of materials. Degradation and sustainability of materials has been added to the unit syllabus at the request of Engineers Australia. The unit is presented as follows: three one hour lectures and one one hour tutorial per week, one two hour practical per fortnight. In addition to the above students can access on a weekly basis a set of on-line tutorial problems for further practice. The textbook for this unit is University Physics by Young, H. D. and Freedman, R. A.

Assessment
Assessment consists of a mid-year class test worth 20%, five fortnightly laboratory reports worth 10%, a practical examination worth 10% and a final examination worth 60%. A weekly set of numerical problems based on the lectures for the week are discussed in tutorial classes. These are not assessable but are used to discuss difficulties students are having trying to solve the problems. It gives the students an opportunity to get face to face assistance which they find extremely useful. Students are also given problems which they can do on-line for further practice. They use the MasteringPhysics online tutorial and assessment system. They get immediate feedback from the computer software. Students find this computer based on-line tutorial system useful for enhancing their understanding of the unit content and also for revision purposes.
Results of the survey
The students enrolled in the Physics & Materials unit completed a pre (Expectations) at the beginning of the semester and a post (Experiences) at the end of the semester survey as part of the Service Teaching Strand of the ALTC/Carrick Project, Forging New Directions in Physics Education in Australian Universities. 35 units were submitted by 22 universities for the survey. On the basis of these surveys, the unit Physics & Materials was ranked in the top 3 out of 35 units in the area of relevance and links between physics and the students’ major area of study. The three top units were from UWS, Flinders University and South Australia University.

The survey showed that:
(a) the students found the unit to be a valuable part of their degree (ΔBA = -0.09)
(b) the students were able to see clear links between what was taught in the unit to their major area of study (ΔBA = -0.06)
(c) the students felt that the lecturer succeeded in linking the material taught in the unit to their major area of study (ΔBA = -0.04)

Comments and conclusion
The main reason for the good performance of the unit Physics & Materials in the survey I believe was that the unit was designed to illustrate how the principles and theories of physics have practical applications in the areas of engineering studies that the students were studying. In short, the students could see the relevance of physics in engineering. I also believe that the brief asides on interesting aspects of the lives of physicists and engineers and the historical aspects of the development of theories and concepts both enlivened and stimulated an interest in physics and engineering. The tutorials and hands-on physics practicals which illustrated the material covered in the lectures also assisted the students in understanding and appreciating the theoretical foundations of physics and their applications in engineering. It is also interesting to note that the yearly Student Feedback on the Unit (SFU) surveys conducted by the University of Western Sydney have always returned high ratings for this unit. The independent ALTC/Carrick survey validates the conclusions of the UWS Student Feedback on the Unit surveys for this unit. In conclusion, I must say that the students we taught were highly motivated individuals who had decided in their high school days to become engineers and builders of the nation. One of the most exciting things I found in teaching them was the great diversity of their cultural backgrounds, views of the world and value systems. They represent the face of modern Australia in the 21st century.

Physics 1A / Physics 1A (extended) (Flinders University) – MODEL 1 subject

Co-ordinator - Jamie Quinton

Fostering Students’ Love of Physics
Are you worried about Physics major student numbers? There is no doubt that we are all concerned with the ongoing decline in Physics across Australia. When I arrived at Flinders University in 2003 the first year Physics program was quite ‘old’ and ‘stale.’ Through declining staff numbers during the 1990s, the material taught at first year level had been whittled down to the ‘essential’ content that needed to be covered for students who planned on progressing to second year Physics. Revision of the efficacy of the laboratory course had not occurred for several years and the equipment was... well... let’s just say rustic. Most notably,
there was an apparent lack of focus on the student experience (which I felt was the crucial driver for maximising experience, retention, and if not these, then at least the overall perception of the relevance of Physics). Rather, the focus appeared to be on the content that was covered. At the time, I observed (and have continued to do so over some years now) that many science academics expect that if a student accumulates a specific collection of facts, the process through which they acquire them provides all of the training they will need. Indeed, to make a contentious sweeping generalisation, this seems to be quite a prevalent ethos in Physics. I found teaching into Physics 1A at that time to be quite demoralising and resolved to promptly improve the situation. With student retention as a primary objective and a focus on their positive learning experience as a route to success, the entire 1st year program was revised in 2005 from the ground up (with the exception of the constraint that we deliver three lectures and one tutorial each week, and one laboratory each fortnight). I would like to relate some key aspects of our first year topic, which has contributed to a tripling of the rate of retention in Physics at Flinders.

Structure and Content
The 1st semester topic (at Flinders, `subjects' are called `topics') Physics 1A contains Cosmology, Classical Mechanics, Waves and Oscillations, Sound and Light and Special Relativity. The topic has remained calculus-based and is undertaken by students who tend to major in Physics within the BSc course or another enabling Science such as Mathematics, Chemistry, or Nanotechnology (the extended version of the topic is taken by students in the Enhanced Program for High Achievers who elect to do it). Enrolment is typically ~60 students (with typical TER >70) in Physics 1A and ~8 students in Physics 1A (extended, with typical TER >90). The topic is assessed in the following manner: Competency tests (3 of these spread over semester, worth 0%, but must be successfully completed before the student is allowed to sit the final exam), 1 take home assignment each week (taken from assigned tutorial questions, worth 10%), online (fortnightly) quizzes (10%), practical reports (x6, worth 30%), and the final exam (worth 50%, but the students must pass it as a requirement for successful completion of the topic).

Maintaining student engagement
The topic is designed to foster student engagement. The content is placed in a deliberate order to start and end with content that is less familiar (and thus hopefully not repetitive from year 12) to the student, and is interesting, or better yet - captivates the students. Starting with cosmology makes a strong positive first impression, and provides a vehicle for the linking of concepts from the more traditional, `essential' content later as they are covered). In addition, the laboratory course has been redesigned to maximise the experience of the students, and most importantly, follows the thematic areas of the lectures as closely as possible. The competency tests occur in weeks 3, 7 and 11 of semester, and students must achieve a minimum score of 70% in each and all tests in order to be allowed to sit the final examination. Where a student does not achieve that score, they are supported through extra tutorial sessions and re-sits once each week to successfully complete the requirement. The majority of students complete these tests without great difficulty, as the questions are set at an elementary level and are worth a zero or a full mark, with the idea being “this is the minimum knowledge that must be attained in 1st year”. In combination with the weekly assignment tutorial question that is marked and feedback provided, these maintain student engagement with the material throughout the semester. In addition to the formal topic structure, in 2008 we also ran a Transition to University Physics activity during Orientation Week that allowed the Physics 1 students to meet each other, their lecturers and tutor, and higher year students.
Through a series of fun activities, the students feel comfortable with each other and their teachers before going to their first lecture. This reduction in student anxiety, in my opinion, increased the impact of the first set of lectures.

Survey Responses and Analysis

This topic scored very well in questions 1, 3 and 9 of the expectations and experiences surveys of the ALTC project, in particular on questions 1, 3, and 9, which were, namely:

- It is apparent to me that this subject is a valuable part of my degree;
- I am keen to see how this subject links to my major area of study; and
- I expect the links between this subject and my major area of study to be made obvious throughout the semester.

Being a topic for Physics majors, any Physics 1A topic (you would think) would not need to work too hard to get good scores on these questions, as it is relatively easy to provide relevance of Physics content to a Physics major. However, I believe that the key influence that turns good scores into very good scores is the student experience that we provide.

Some student responses included (Expectations: “I expect to become a lot more competent in real life situations after this! School never gave me that!” “I expect to be able to learn and apply physics in a practical sense, not just learn theory.” “I expect this subject to help round out my understanding of biology, looking at it in new ways.”) and (Experiences: “It has been highly enjoyable. Physics is awesome man!” “Overall, Physics 1A was a positive learning experience. Labs helped me get a better understanding of the topic.” “Very relevant, information that was presented was applicable to daily life.” “With what I have experienced for this topic I truly enjoyed lectures. Most of the time they were entertaining.” Of course, you will never be able to please everybody. Consider these! “Although pracs may be improved, more fun needed. i.e. blow up stuff!” “Include more interesting topics like superstring theory, Hold screening of good documentaries.” It is pleasing that our students had a quite positive experience, but there is still room for improvement (I’d prefer that the student experience exceeds their expectations). Finally, I’d like to ask some thought-provoking questions. We are all passionate about Physics - that is of course why we are Physicists. How do you share that passion with your students? Do you feel that you create the optimal learning environment in your classes? In that environment, what is it that you do to ensure its efficacy? How do you reach your students? Do you attempt to teach them from inside their comfort zone, or do you try to make them come into yours?

A theme that emerges from the co-ordinators’ comments is the passion with which they have developed their subjects. Student engagement is given high priority: “Fun activities”, “applications [of physics] to the building of bridges” and “a subject deliberately designed to provide the physics knowledge required by radiation technologist” were cited as factors that promoted engagement.

Examples abound in Ragbir Bhalal’s account of where the physics related to engineering were deliberately included to emphasise to students the relevance of physics to their engineering studies. Nick Mermelengas also emphasised the importance of relevance and also characterised many of students as highly motivated and high achievers. Student comments included by Jamie Quinton in
his piece, such as “information that was presented was applicable to daily life”, indicate that students appreciated the lengths taken to emphasise the utility of the physics taught.

Regular tests were credited by Jamie Quinton as important in maintaining student engagement and it is notable that Nick Mermelengas also incorporated several short quizzes, which were valued by students as they allowed them to “stay on top of our workload”.

Underpinning the approaches adopted in the design and delivery of their subjects was the positive attitude of the academics towards their students and a commitment to continuous subject development: “it is pleasing that our students had a quite positive experience, but there is still room for improvement” (JQ), “…they were a pleasure to teach” (NM) and “one of the exciting things I found in teaching them was the great diversity of their cultural backgrounds” (RB).

A brief survey was sent out to the academics who administered the surveys to gauge their opinion of the value of the surveys. The four questions they were asked were as follows:

1) Have the results from the expectations/experiences surveys that you received for your subject(s) been of value to you? If so, can you say briefly in what way(s)?
2) Are there additions/modifications that you would suggest to the surveys to make them more useful?
3) Was there anything surprising in the student survey responses?
4) (Assuming you are required to carry out a student survey at the end of the semester.) Do you think the A/B surveys are of more value than your 'standard' end of semester survey? If so, in what way(s) are they superior?

There was general consensus that the expectations surveys had been valued (question 1) and indeed in some cases the findings had been acted upon promptly:

“The results were of great value for me, especially where the changes in perception of certain aspects were statistically significant.” And from the same academic: “Based on these data, I've modified the teaching strategy in the second semester. As a result, the preliminary student feedback was very positive, and their understanding of the subject and its main concepts has improved significantly compared to the same semester in 2007.”

Other academics responding to question 1 wrote:

“Of definite value, yes! We have used them to inform our practices of assessment and topic delivery.”

“Yes, the results have been valuable in identifying aspects which we can improve, and also aspects which we probably can't change but can explain better to the students.”

With respect to possible modifications to the questions (responding to question 2), some were unsure and one made the point:

“I thought they were reasonably comprehensive while remaining focused on expectations and experience. My concern would be that if more questions were added, it would dilute the overall quality of the survey. I believe that you will get
"the most well-thought out responses from the fewest possible number of questions."

Academics did admit that surprises were contained within the survey responses (question 3):

From one academic: "Labs are not seen as a positive and valuable experience and in [the expectations survey], more students would advise others not to take physics."

Another academic also remarked on comments made by students about labs:

"It was interesting to note that we still need to work on our lab experience for the students (given that they were redesigned a few years ago). It further suggests that the lab experience dominates the students’ perceived experience."

When comparing the expectations/experience surveys with their usual end of semester surveys (question 4), the consensus was that each survey was focusing on something different, such that they were regarded as complementary, rather than competing surveys.

"I cannot compare the value of expectations/experiences surveys with our standard survey on the same scale. To me, they all are very valuable (maybe because I am a new academic, so any feedback is important), but in different ways - like apples and oranges."

Another academic remarked:

"These surveys are more valuable because they provide information relating to the ‘service’ nature of the course which is not captured in the standard Student Evaluation survey …The before/after aspects of these surveys are not captured in the end-of-semester survey."

And finally:

"I believe that they certainly complement the existing student evaluation (SET) process. However, the ALTC project surveys provided a better measure of the holistic student experience, as these were explicitly measured against the students own expectations, rather than against a generalised perception (which occurs with open-ended questions in SET). SET questions deal with bottom-up (specific details), rather than the overall experience (which these surveys did), in general."

For the questions analysed so far in surveys A and B there is some indication in the data, though not conclusive, that the type of model 1, 2A or 2B in which students are enrolled has an influence on student views of the subject (see Figure 5). This issue requires further exploration. The finding that the mean survey B scores for the questions relating to links (Q1, 3 and 9) is less than the mean scores for the corresponding question in survey A is consistent with that found in the pilot study of 2007. Question 9 in particular, with the shift of the mean score from something approaching 4 in survey A to a mean score of 3 in survey B may be of concern, especially for model 2B subjects, as this points to a lack of success in linking the subject to area in which students are majoring.
The laboratory based question showed that student experiences did not match their expectations, irrespective of the type of subject they were enrolled in, and this is strongly reinforced by the responses to the open-ended questions. More detailed analysis of the open-ended responses concerning labs is called for, including whether there is any relationship between the type of subject and the frequency of negative comments. This work also points to a need to look more specifically at the physics laboratory experience of students who are not majoring in physics, in order to establish which laboratory related issues, such as the relevance, resourcing, or links to lectures, are most highly regarded by students.

8. Final comments and reflections

We believe that this study into identifying, promoting and disseminating good practice in service teaching has been extremely valuable and has offered evidence instead of anecdote with regard to student expectations and experiences of a physics service subject. Did we learn anything that we couldn’t have guessed before we began this project? We guessed that there would be a relationship between the extent links were made between a student’s intended major and the student’s experience of the subject, and this was supported by this study. What did surprise us was the extent to which physics laboratories in service subjects are regarded almost uniformly poorly across many institutions. We conjecture that while subjects might have done well in linking the physics to the major with respect to content, has the same special effort been put into designing a laboratory experience for students in service subjects that similarly links physics to the major area of study? This project is not able to answer this question, nor whether such a special effort would make a difference. We guess that it would, but addressing this question must be a focus of another project.

The results presented in this report form only a subset of what can be derived from the survey data collected. We believe that a thorough consideration of responses to the questions in Table 6 will offer further insights into student perceptions of the value of the service subject to their immediate and future needs.

Acknowledgements

We acknowledge the large number of physics academics across Australia who administered and collated the surveys reported here. We also acknowledge the excellent support provided by Mr Antoine Goarin (and his staff) of the Planning and Quality Unit at UTS. Support for this work has been provided by the Australian Learning and Teaching Council, an initiative of the Australian Government Department of Education, Employment and Workplace Relations.
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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), is causing departments to rethink teaching and learning strategies. In addition, understanding of graduate destinations becomes 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.

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; and
- Providing some 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 its trial, with the result that the employer questions closely complimented those of the graduate survey.
Both surveys were finalised at the beginning of 2008 and were placed online at SurveyMonkey, a professional survey hosting website, in February. 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, but this only happened effectively at a small group of institutions. Only four departments had ready access to an alumni database. Of these, only one (The University of Sydney) maintains a physics-only alumni list. The other three (The University of Adelaide, CQUUniversity Australia 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 lack of ready access to alumni lists is an interesting 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 seven universities, but these span a wide range in size and location:

- CQUniversity Australia
- Murdoch University
- RMIT University
- The University of Adelaide
- The University of New South Wales
- The University of Sydney
- 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); and
• 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.

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 take part 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 rough 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 learning and teaching issues. The main statistics characterising the sample are:

- Number of graduates in reduced data set = 108;
- Female to male ratio = 35 / 71 (1:2);
- Mean age = 33 years; and
- 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)](chart.png)

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 and postgraduate degrees
(n = 108)

- doing a Physics MSc 1
- doing a Physics PhD 7
- have a physics MSc 3
- have a physics PhD 39
- have no postgraduate degree in physics 58

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; and
- Number of graduates with no postgraduate qualifications = 42.

3.4 Reasons for doing physics

There were numerous reasons given for choosing to study physics at university (Figure 4). The three most cited are:

- A deep interest in physics;
- Enjoying the subject and/or getting good results in high school; and
- 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.

![Figure 4: Reasons for respondents studying physics at university.](image)

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 (over). The average time spent in the first job was three and a half years.
<table>
<thead>
<tr>
<th>Position</th>
<th>Employer</th>
</tr>
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<tbody>
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<td><strong>Miscellaneous</strong></td>
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<td>Boston Consulting Group</td>
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<tr>
<td>Mortgage Broker</td>
<td>Aussie Home Loans</td>
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<td>Dairy Farmer</td>
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<tr>
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<td>Marketing</td>
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<td>Davies Collison Cave</td>
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<td>IP Australia</td>
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<td>IP Australia</td>
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<tr>
<td>Special Counsel</td>
<td>Minter Ellison</td>
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<tr>
<td><strong>Financial Maths</strong></td>
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<tr>
<td>Derivatives Dealer</td>
<td>Schroders (now part of Citigroup)</td>
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<td>St George Bank</td>
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<tr>
<td><strong>Defence Force</strong></td>
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<tr>
<td>Operational Analyst</td>
<td>ADI Limited (now Thales Australia)</td>
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<td>Engineering Officer</td>
<td>Air Force</td>
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<td>Science and Maths Teacher</td>
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<td>Science Communicator</td>
<td>Questacon</td>
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<th>JSPS Postdoctoral Fellow</th>
<th>KEK - High Energy Accelerator</th>
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<td>Health Physicist</td>
<td>Australian Radiation Services</td>
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<td>Postdoctoral Research</td>
<td>European lab for non-linear spectroscopy</td>
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<td>CSIRO</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>
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**Private Sector (Science and Engineering)**

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<th>Technical Instructor</th>
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<td>John Holland Group</td>
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<tr>
<td>Standard Engineer (contractor)</td>
<td>Canon Information Systems Research Australia</td>
</tr>
<tr>
<td>Quality Control Officer</td>
<td>Raflatac Oceania</td>
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<tr>
<td>Solar Cell Designer / Maker</td>
<td>Dyesol</td>
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<tr>
<td>Production Support Engineer</td>
<td>Phonak &amp; Unitron Pty Ltd</td>
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<tr>
<td>Research Scientist</td>
<td>Fluorosolar Systems Ltd</td>
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<tr>
<td>Civil Engineering Programmer</td>
<td>Keays Software</td>
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<td>Technical Officer</td>
<td>GHD</td>
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<tr>
<td>Project Engineer - Instrumentation &amp; Controls</td>
<td>Esso Australia Ltd</td>
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<tr>
<td>Senior Systems Supervisor</td>
<td>Queensland Alumina Limited</td>
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<tr>
<td>Electrical &amp; ESD Engineer</td>
<td>EMF Griffiths</td>
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<td>Project Officer</td>
<td>Direct Edge Corporate Development</td>
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<td>Avionics Engineer</td>
<td>Jayrow Helicopters</td>
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<tr>
<td>Health Physics Technician</td>
<td>CH2M Hill Pty Ltd (and ThermoNutech)</td>
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<td>Physicist/Mine Radiation Safety Officer</td>
<td>WMC Resources / BHP Billiton</td>
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<tr>
<td>Research and Design Manager</td>
<td>RTUNet</td>
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</table>

(continued over)
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.

<table>
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<td>Lecturer</td>
<td>Murdoch University</td>
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<tr>
<td>Tutor / Marker / Observer</td>
<td>University of Tasmania</td>
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<tr>
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<td>Research Officer</td>
<td>Central Queensland University</td>
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<tr>
<td>Senior Technical Officer</td>
<td>University of Tasmania</td>
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</table>

**Table 1:** The range of positions taken up by physics graduates upon graduating.
Interestingly, of these graduates (with only an undergraduate degree) none go into secondary teaching or medical physics.

Figure 6 compares the job sector breakdown between those graduates with and those graduates 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 go into secondary teaching or medical physics.

Figure 6: Job sector breakdown for initial employment - difference between those with, and those without, postgraduate qualifications.
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 7: Job sector breakdown for current employment of physics graduates.](image)

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.

![Figure 8: Job sector breakdown for current employment – difference between those with, and those without, postgraduate qualifications.](image)
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 however that a smaller physics component would be useful training for their current job

Additionally, 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 (a different question to the one on recommending a major in physics, i.e. in above bullet points), 68 feel that it is has been, seven were not sure and only six felt that they gained no advantage.

Highly-ranked 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.
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).

Figure 9: Helpful features of a physics degree that foster learning.
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.

![Graduate attributes developed in undergraduate physics](image)

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 strongly suggestive of the above-mentioned possibility, 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. As far as graduates are concerned, this is far and away 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.
Figure 11: Percentage of graduates believing certain graduate attributes require more development in undergraduate physics.

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; whilst the majority of graduates state it is given scant consideration, only one-quarter of them believe it 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.

<table>
<thead>
<tr>
<th>Graduate Attribute</th>
<th>Better developed by</th>
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<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>
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</table>

Table 2: Disciplines where graduate attributes are better developed in undergraduate studies.
Some interesting quotes regarding skills not well developed in physics:

“Design, and ethical considerations were more emphasised in electrical engineering. 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.”

“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:

“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 what it is in undergraduate.

![Graduate attributes developed in postgraduate physics](image)

**Figure 12:** Extent of the development of graduate attributes in postgraduate physics, as ranked by graduates.

![Attributes needing more attention in postgraduate physics](image)

**Figure 13:** Percentage of graduates believing certain graduate attributes require more development in postgraduate physics.

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

Forging new directions in physics education in Australian universities

Appendix 4 – Graduates in the workforce working party report, John O’Byrne and Alberto Mendez
will 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 on, 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 (quite visible) 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 the 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 difficult.

4.3 Sample responses

Below we reproduce a selection of graduate responses which highlight the issues summarised in the preceding paragraphs. The bold text emphasis is by 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 their ability 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 then 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 so 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. Their 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:

"Some aspects 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.

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Figure 14: Extent of the development of graduate attributes in undergraduate physics, as ranked by employers.
One 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

6.2.1 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 graduates for the survey, the state distribution changes is driven by CQU results.

6.2.2 Range of tertiary qualifications

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

6.2.3 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,
remain unchanged across the different subsets. The only slight difference is that at The University of Sydney as many students mention the overall second placed reason as the first.

6.2.4 First job after graduation

Few graduates who have no postgraduate qualifications stay in the university system. None of these graduate go 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 get female graduates.
6.2.5 Current / most relevant job

The picture is very similar to what it is for the first job. The biggest difference between the subsets is that only one in seven Sydney University graduates is still in their first job.

6.2.6 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%).

6.2.7 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.

6.2.8 Graduate Attributes

Graduates with physics postgraduate degrees
- Almost identical rankings, similar scores
- Slightly increased scores (+0.15 or more):
  - problem solving, research methodology, oral communication
- Slightly decreased scores (-0.15 or more):
  - ethics, project planning

Graduates with NO postgraduate qualifications at all
- Almost identical rankings but somewhat lower scores
- No slightly increased scores (+0.15 or more)
- Slightly decreased scores (-0.15 or more):
  - problem solving, research methodology, oral communication, computational skills

Female graduates
- Almost identical rankings, similar scores
- Slightly increased scores (+0.15 or more)
  - information retrieval, computational skills,
- No slightly decreased scores (-0.15 or more)

The University of Sydney graduates
- Almost identical rankings, similar scores
- Slightly increased scores (+0.15 or more)
  - teamwork (+0.5), ethics, project planning,
- Slightly decreased scores (-0.15 or more)
  - Computational skills

6.2.9 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

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