Physics learning and teaching in Australian Universities

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Abstract

A comprehensive study of undergraduate physics learning and teaching in Australia reveals physics departments being challenged within a rapidly changing tertiary environment, where both funding per student and the physics share of the expanding tertiary market have been in decline for decades. Departments have responded in a variety of ways: developing new courses, introducing novel technologies and large- and small-scale restructuring of curricula. This study investigated current teaching methods and learning outcomes, and the role of multidisciplinary and service teaching, which is vital to the health of most departments, be they a physics department or another discipline in science. The main results of the study and some future directions are presented here.

Introduction

Accountability for the quality of learning and teaching in higher education is receiving increased public scrutiny worldwide (Hersh, 2005; Jaschik, 2006). Coupled with this are concerns about declining enrolments and student interest in pursuing physics studies at university. It is within this context and with the intent of understanding and improving university physics learning and teaching that key international studies have been undertaken. In 2000/1 the Institute of Physics (IOP) carried out the Inquiry into Undergraduate Physics in the United Kingdom, in 2001/2 the American Association of Physics Teachers (AAPT) established the National Task Force on Undergraduate Physics and in 1997/8 the European Physics Education Network (EUPEN – a consortium of more than 100 physics departments in over 30 different European countries) conducted a comparative study into undergraduate physics throughout Europe.

An analogous study into undergraduate physics education in Australia was conducted in 2004/5. The Australian Universities Teaching Commission (AUTC) and the Carrick Institute for Learning and Teaching in Higher Education funded the project, entitled *Learning Outcomes and Curriculum Development in Physics*. The project team included academics from 13 institutions across Australia and a panel of expert advisors. The purpose of this paper is to provide a brief description of the Australian study, to highlight its key findings, to make comparisons with the international studies cited, and to outline the implications for the future of learning and teaching of university physics in Australia. The content is drawn from a report (Sharma, Mills, Mendez & Pollard, 2005) produced at the end of the first stage of the study.

International studies on undergraduate physics education
The Institute of Physics *Inquiry into Undergraduate Physics* (2001) surveyed physics departments and students throughout the United Kingdom. The study's main conclusions were:

- Physics provides the foundation for all of engineering and many scientific disciplines including Information and Communication Technology (ICT), the geosciences, biomedicine and the life sciences.
- Physics education develops strong intellectual and practical skills, well matched to the evolving needs of employers.
- The overall numbers of physics degree graduates have been maintained in the 15 years prior to 2001 but there are growing employer demands for scientists and engineers that are not being met.
- There is a critical shortage of physics teachers in secondary schools, with two thirds of physics taught by teachers without a physics degree.
- There is a drop in the number of undergraduate physics courses offered in regional universities.

In the United States, project Strategic Programs for Innovations in Undergraduate Physics (Hilborn, Howes & Krane 2003) was organised by the National Task Force on Undergraduate Physics as part of an eight-year long effort. It set out to answer the question, *'Why during the 1990s, when student numbers in physics were falling all across the USA, did some departments have thriving programs?'* In-depth studies of 23 such thriving departments were conducted and the following common features emerged:

- The attitude that it was their responsibility to maintain or improve the undergraduate program (albeit in the face of funding difficulties).
- A supportive and encouraging program which includes advising and mentoring, an undergraduate research participation program and a strong sense of community encompassing students and staff.
- Strong leadership and a clear vision for its undergraduate program.
- Strong disposition toward continuous experimentation and evaluation of its undergraduate program.

A number of European countries have also undertaken national studies of the physical sciences and have reached similar conclusions to those above.

The Australian context
Physics Departments The Australian university system is relatively small, consisting of approximately 40 tertiary institutions which are predominantly publicly funded. Three quarters of all institutions are located in the state capitals, although many of these have additional campuses in rural areas. At the time of the study 34 institutions had an identifiable physics department, consisting of at least two full time permanent academics teaching physics. Within these 34 physics departments there is great diversity, in terms of size, resources and focus. Departments range in size from only a couple of academics that have a service teaching and/or applied physics focus (with few or no research options), to large schools that teach a broad range of traditional physics subjects and have extensive research programs. Most physics departments, regardless of their makeup, are significantly involved in multidisciplinary degrees and service teaching.

Degree structure The typical undergraduate physics pathway in Australia is via completion of a three-year Bachelor of Science degree, with an extra year for Honours. Completing a progression of physics subjects in all three years of the degree usually constitutes a 'physics major'. We define a 'physics major' as a degree program comprising of a substantial fraction of physics courses, including studies in the third year. Students intending to undertake a physics major are expected to have completed both physics and mathematics (including calculus) in their final year at secondary school. As the school curricula is determined by states, universities take diverse approaches to addressing the issue of differing background high school knowledge. Students completing the three-year Bachelor of Science degree with above average grades can enrol in a fourth year Honours degree.

Completion of the Bachelor of Science (Honours) degree is generally the minimum prerequisite for postgraduate studies, akin to the traditional UK degree system in that progression to PhD is also possible from Bachelors only. Students can then enrol in a Master of Science (1-2 years) or Doctor of Philosophy (3-4 years) postgraduate degree. Entry into the PhD program requires high marks in the Bachelor of Science (Honours) degree rather than completion of a Master of Science degree. This is in contrast with the European model, where degrees are in the process of being standardised to a 3+2+3 year structure (Bologna Declaration), and the two-year Master degree is a requirement for progression into the PhD program.

Another path that has become more common in recent years is the double or combined degree (a degree program which fulfils the requirements for two degree programs). In these courses, the two degrees are undertaken with some amount of overlap and often completed in five or six years.

A full description of the Australian model is given in Sharma et al. (2008).

Student numbers Although the Australian university student population has more than doubled in the last 20 years, the number of students taking a physics major has changed sporadically. Third and fourth year numbers in physics (as shown in Figure 1) experienced significant decline in the period 1994 to 2001, but have since shown modest increase in fourth year numbers and a dramatic increase in third year numbers. It is yet to be seen if this reversal will be sustained, but there are clear indications that numbers are increasing again (de Laeter, Jennings & Putt, 2005). Plausible reasons for the disparity between overall increases and physics numbers (the changing nature of students and courses in the last decade) are discussed in this paper.

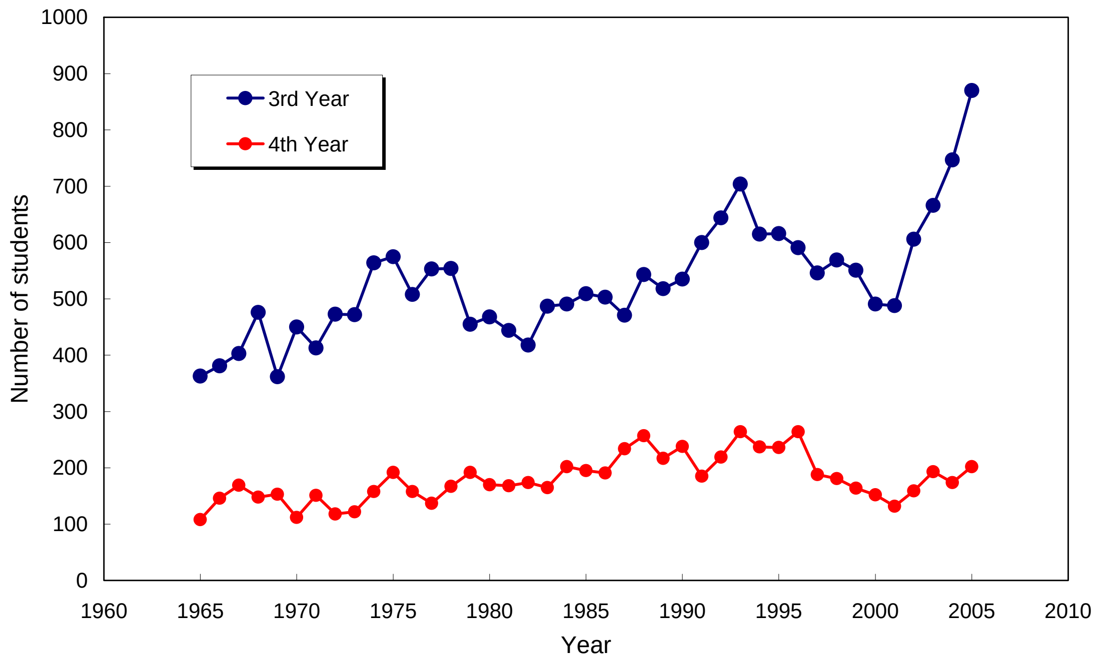

Figure 1. Third and fourth year physics program enrolments at Australian universities 1963 – 2005 (adapted from de Laeter, Jennings and Putt 2005)

Method

First stage

The key objective in the first stage of the project was to document and evaluate the learning and teaching of physics in Australian tertiary institutions. This objective was attained via substantial data collection in the first year of the study. The data collection instruments and all project information can be found at the project website (Learning Outcomes and Curriculum Development in Physics, 2005). A predominantly open-response questionnaire, which was completed by all 34 physics departments, sought details about current issues for mainstream, multidisciplinary and service teaching, changes, challenges and responses, new initiatives and strengths, the interface with employment, staffing and teacher training. The data analysis was performed by identifying emergent themes, and iterative coding of these themes. These were compared and contrasted across questions to extract dominant and/or recurring themes. Having extracted these dominant themes, nine departments capturing the diversity in departmental structure, geographic location and student population, were then selected for follow-up interviews with heads of departments, leaders of academic programs, and focus groups of students. The data from these interviews were again compared and contrasted to confirm the dominant themes.

Second stage

The main objectives in the second stage were to strengthen the network of tertiary physics educators and to disseminate the good learning and teaching practices identified in the first stage. Workshops were held to reinforce networks and to foster and recognise innovative and effective approaches to learning and teaching in physics. A selection of good practices, drawn from a large number of departments and covering diverse features, was published (Mendez et al., 2005) and distributed throughout the Australian physics community.

Additionally in the second stage, physics graduates and their employers were interviewed in order to gauge the value of a physics education in the workplace (Sharma et al. 2008).

Findings

The key findings of the study are of global interest and complement those of the similar international studies mentioned earlier. We have categorised the findings under three headings: Departments, Physics Major and Learning Physics.

Departments

Internationally we see trends for universities to be managed along corporate business lines (Hodges, 2002). This is mirrored in Australia through increasing demands being placed on universities. Distribution of funds is becoming directly coupled to research output, number of students being taught and quality of teaching (Ramsden & Martin, 1996). The metrics for measuring research output are evolving, but widely used. Measuring quality of teaching is more difficult and therefore less significant in deciding funding.

Within universities similar measures are being introduced to allocate funds to departments. Departments are then grappling with issues of how best to allocate resources, in order to sustain areas of strength and nurture weaker areas. With this in mind we tried to capture the range of challenges faced by departments in offering quality and attractive physics learning and teaching, and the strategies for responding to these challenges.

Challenges Physics departments were asked, '*What challenges has your department faced in physics learning and teaching in the last 3-5 years?'* The most common responses given by the 34 physics departments surveyed in 2004 are shown in Figure 2.

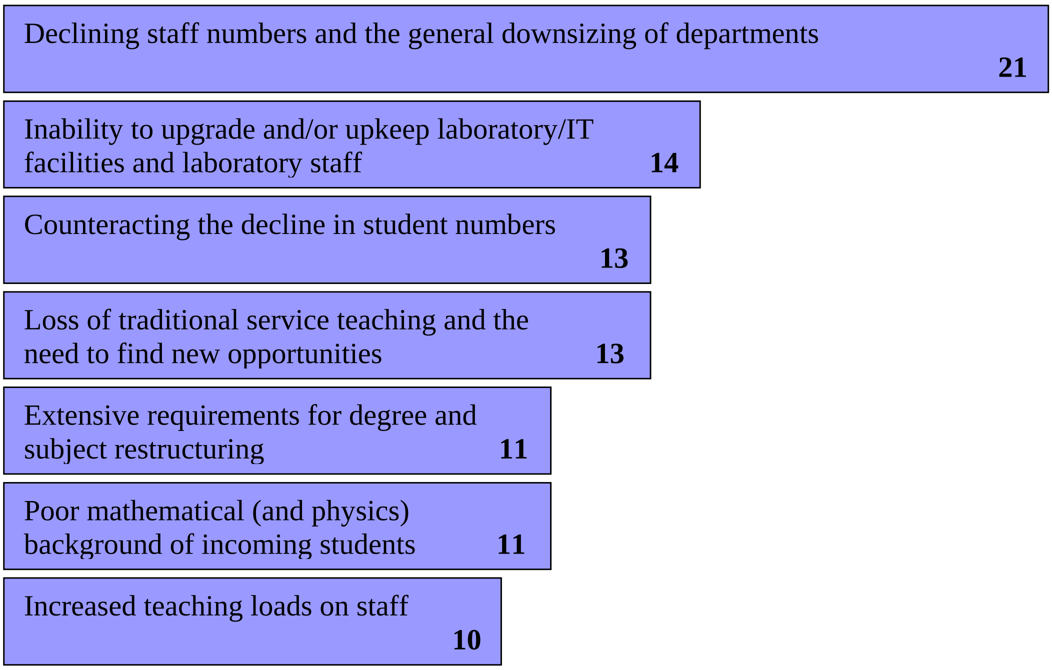

Figure 2. The main challenges affecting learning and teaching in Australian physics departments, and the number of departments citing each.

The main issues raised by departments appear to be largely interconnected and, clearly, the effective decline in recurrent funding over the last few years has meant that many departments have become smaller and have struggled to maintain resource levels or improve facilities. To quote one statistic, between 1995 and 2004, total public funding per student for tertiary institutions in Australia has declined 27%, compared to an Organisation for Economic Co-operation and Development (OECD) average rise of 5%, and a much larger rise in many comparable countries (Marginson, 2007). Taking one large Physics department as an example, the teaching staff dropped from around 40 to 20 in that period. Significant downsizing and declining staff numbers were mentioned by almost two thirds of the 34 departments. The decline in student numbers is also a genuine concern for many departments, confirming the implications of the data presented in Figure 1.

Strategic responses and future directions Departments have responded to these challenges in a variety of ways (see Figure 3). Many departments have been able to make improvements in student retention rates, primarily through the restructuring of curricula and the introduction of new learning technologies.

The responses being employed by departments are not purely reactive but part of a strategy to position themselves for the future. When asked about future directions, over half of the departments cite strategies revolving around the continued introduction of new and innovative courses and degrees. The introduction of courses and degrees that are attractive to students, such as Nanotechnology and Forensic Science, are usually accompanied by new alliances and creative marketing. The second most popular strategy amongst departments is to increase the online delivery of subjects. This is in line with findings from various studies that demonstrate that increasing numbers of students are working while studying, making flexible delivery imperative (McInnis, James & McNaught, 1995). A quarter of all departments report plans to increase service and/or multidisciplinary teaching loads, both with new disciplines as well as strengthening ties with traditional partners.

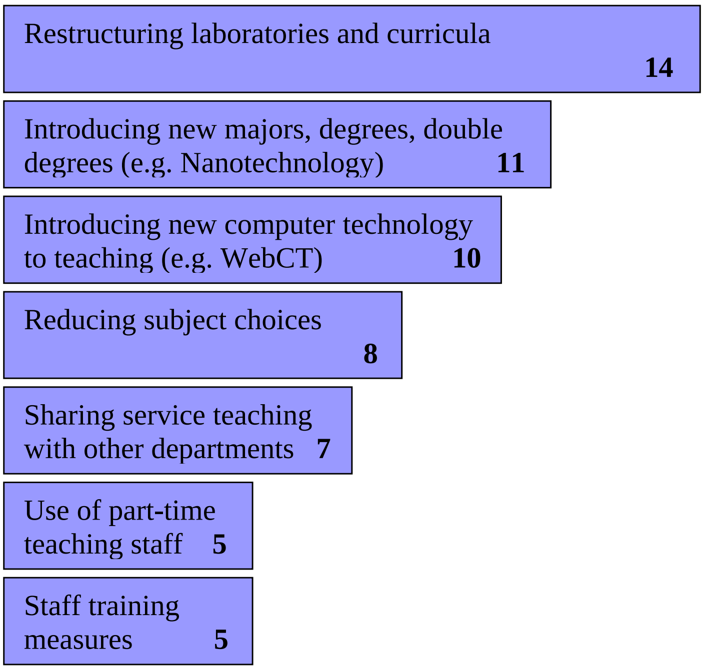

Figure 3. How Australian physics departments have responded to the challenges affecting learning and teaching, and the number of departments citing each.

When reporting on new directions, a smaller number of departments are looking at retention through quality of learning and teaching (such as Mazur, 1997 and for a review article see McDermott and Redish, 1999). Specifically they point to an emphasis on small groups, interactive learning, and a focus on concepts and outcomes rather than content coverage. It is interesting to note that internationally, substantial effort is devoted to physics education research that is investigating some of these 'quality of learning' strategies. Departments are increasingly becoming aware of these strategies and, informed by the findings of the physics education research community, they are able to avoid having to reinvent the wheel.

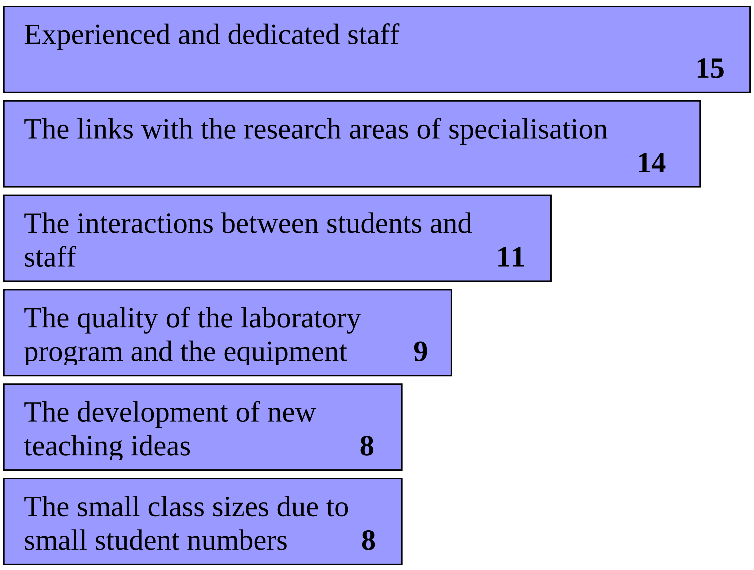

Figure 4. The learning and teaching strengths in Australian physics departments.

Strengths In developing strategic plans and future directions, departments have also had to assess their strengths. The questionnaire asked departments to list what they consider to be their main strengths in learning and teaching. The principal responses are presented in Figure 4. Human resources are greatly valued by physics departments, with both the dedication and expertise of their staff and interactions between staff and students ranking highly.

Service and multidisciplinary teaching Historically in the Australian context, physics departments have not restricted their teaching to the physics major but have taught physics-based subjects to students enrolled in other degree programs. This is known as service teaching. Engineering has traditionally been the dominant client faculty, with first year engineering service subjects comprising a significant proportion of many physics departments' overall teaching load.

In recent years, a variety of factors have caused some service teaching opportunities (especially Engineering) to decline in some institutions. These factors include some degrees becoming postgraduate qualifications, accreditation requirements crowding the syllabus in other degrees, and funding based (in part) on student numbers causing departments to 'reclaim' their students. However, we also notice the emergence of new alliances such as those with the biomedical and health sciences, and agricultural industries.

Service subjects are resourced similarly to mainstream subjects and it is clear that most departments are significantly dependent on this teaching (see Figure 5 for income derived from service teaching).

Multidisciplinary teaching is relatively new and refers to the shared teaching of individual subjects by different disciplines. This has come about largely because of the introduction of multidisciplinary degrees where several departments work together towards a major. Such degree programs are often called *named* degrees. As an example, physics, chemistry and engineering jointly offer degrees in Nanotechnology, Photonics, Biotechnology, Environmental Science and Medical Physics. These *named* degrees usually mirror the research strengths of departments, the current frontiers of science and technology, as well as strategic funding areas identified by governments. These can be shifting goalposts; their implementation requires time, resources and investment for sometimes short-term benefits. However, many departments feel the need to 'keep up', in order to lure students and therefore funding.

The bulk of service and multidisciplinary teaching occurs in first year, often inflating first year numbers and resulting in a dramatic drop in numbers of students doing physics subjects in subsequent years. As an example, at one institution there were approximately 1000 first year students, 150 in second year and 80 in third year. It must be noted that there is great diversity amongst physics departments, and at the other extreme there are departments that predominantly teach physics as service subjects. Consequently, the revenue generated from simply counting the numbers of students enrolled in service courses can be substantial. Although, on average, approximately half of all undergraduate physics is taught to students as a service subject or as part of a multidisciplinary degree, Figure 5 shows there is a huge variance between departments in the proportion of teaching income generated by service/multidisciplinary teaching. This income influences the size and health of physics departments and the range reflects the diversity within the Australian tertiary physics sector.

A fundamental issue for departments then is how to balance the allocation of resources between service/multidisciplinary teaching and teaching the physics major. An additional factor to consider is that students taking a physics major in some cases are not identified until the third year (discussed in detail in the next section). A larger investment in students taking a physics major can lead to increases in postgraduate students and feeds into improved health of the research program, both positive influences on funding. On the other hand, a larger investment in service/multidisciplinary teaching can also result in increased funding. Both are obviously important and finding the right balance is something departments must decode based on their own circumstances.

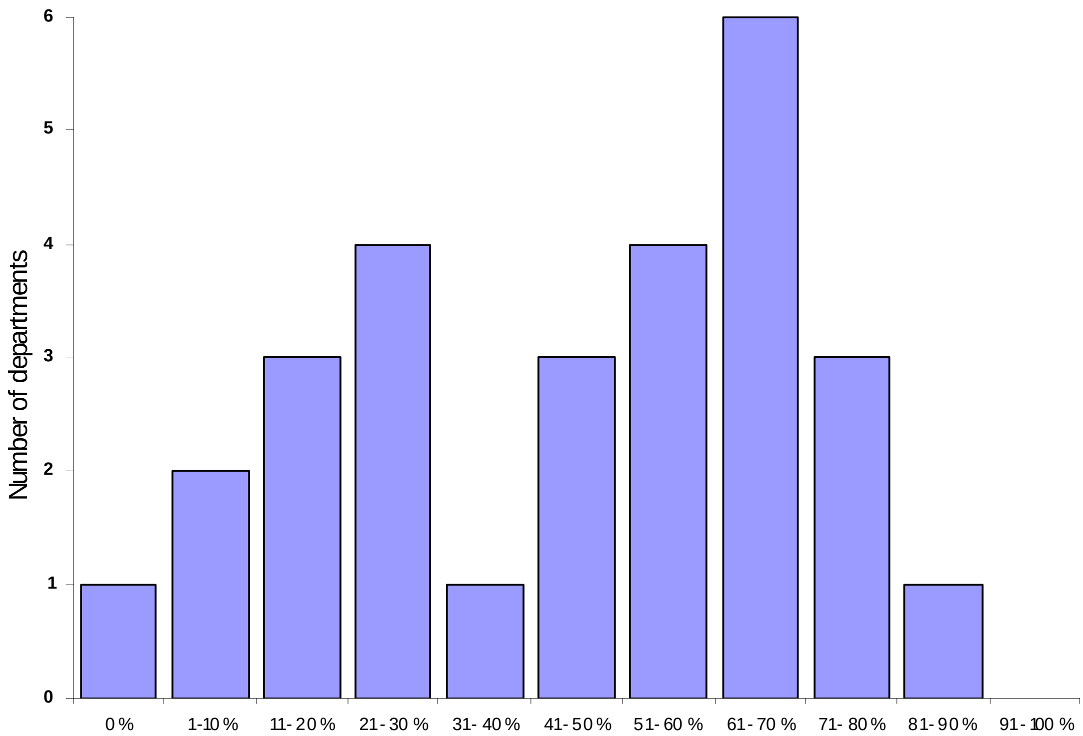

Figure 5. Fraction of departmental income derived from service/multidisciplinary teaching.

Another issue is the perceptions associated with teaching service/multidisciplinary subjects as opposed to teaching subjects in the physics major. Some staff teaching service/multidisciplinary subjects have in the past felt that their work is not valued and supported because of the perception that teaching students that will not be continuing with physics is not as important. This can affect staff morale and enthusiasm, and impact negatively on the quality of teaching. We are aware that patterns are changing so we asked the question, *'How well supported is your service and multidisciplinary teaching?'* Almost two thirds of all physics departments reported that service and multidisciplinary teaching was either supported well or to the same level as other teaching. However, four departments admitted supporting service and multidisciplinary teaching badly and there is anecdotal evidence that many physics departments neglected their service teaching in the past, some of which has since been lost and will prove difficult to re-establish.

Physics major

Typically in a Bachelor of Science degree, students in first year spend at least a quarter of their time studying the subject in which they intend to specialise. The percentage of time studying this subject increases every year: in the second year this figure is at least a third, and by the third year it has reached a half. Of course there are institutional variations and the weightings can vary if students elect to do different combinations, such as a physics major and a chemistry minor or do a double major. In some institutions, students enrol in the general degree program and their choice of subjects in third year identifies their specialisation, which is the reason it is very hard for many physics departments to identify students taking a physics major early on. In other institutions potential students taking a physics major are clearly identified in first year.

Content An initial search through departmental websites provided information on the physics subjects being taught to students taking a physics major in each institution. From these data a listing of generic physics subject areas was developed and provided in the questionnaire. In view of current thinking concerning the critical role of assessment in student learning and the need to align assessment with teaching (Biggs, 2003), we asked *'For each of the following areas, within the entire physics major degree program (excluding honours), please provide an approximate percentage denoting the student time (both contact and non-contact) spent on and the assessment weighting of each area.'* Subject area emphasis in mainstream physics degrees (including double degrees) is shown in Figure 6.

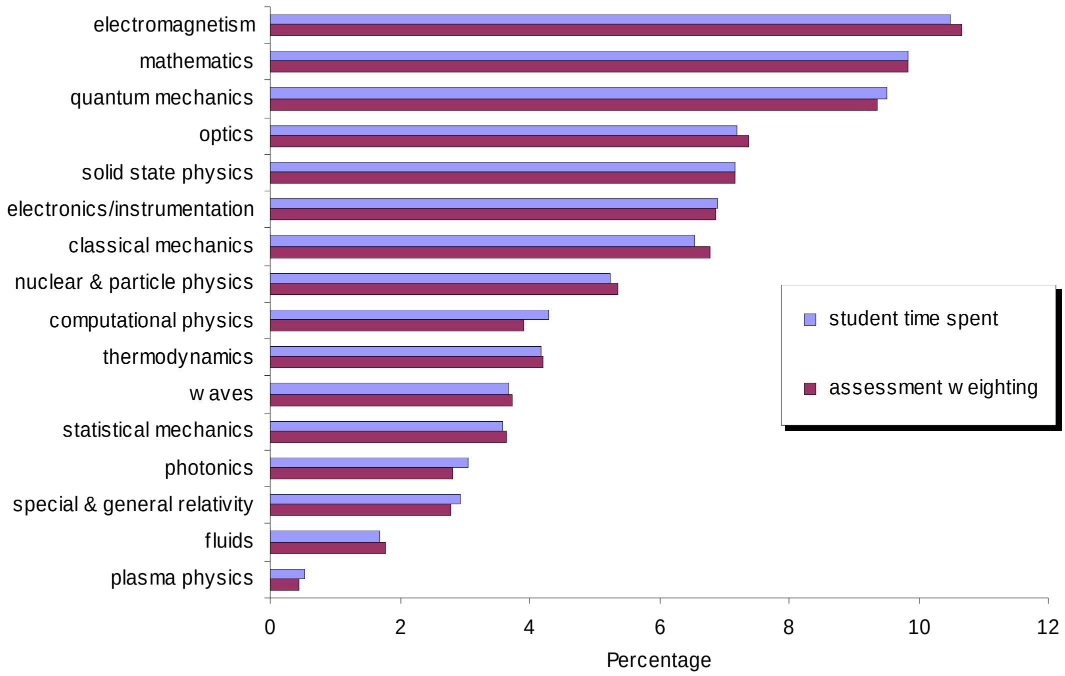

Figure 6. Subject area as a percentage of the mainstream physics degree program, averaged over all departments.

From the perspective of departments there is good alignment between content taught and assessment. This is not surprising as it is relatively easy to compare the two parameters. Interestingly, the second most emphasised content area is mathematics. This was not one of the subject areas identified by the project team but was a category added by many departments. Although not implying that physics departments are teaching mathematics courses, it confirms that a lot of time is spent teaching mathematical skills as part of physics subjects. This concurs with reports from almost two thirds of departments that state that current students entering first year are weaker in mathematics than previously. In general, students taking a physics major are expected to undertake first and second year mathematics subjects (taught by mathematics schools) as part of an accredited physics degree.

Skills Traditionally, the learning and teaching emphasis in a physics undergraduate degree has been on specific physics concepts and knowledge. This has been justified by the extent to which these attributes are required by graduates proceeding to further study or professional science positions. In the last 10-15 years however, physics graduates are increasingly being employed in positions that do not necessarily specify a physicist, and this has seen an increased awareness of the importance of generic skills. The integration of specific and generic skills in degree programs and subjects is now mandatory in most Australian universities. This shift has come about in response to employers' expectations of physics graduates. A study of physics postgraduates in the United Kingdom (Jagger, Davis, Lain, Sinclair & Sinclair, 2001) found that, while they ranked high on problem solving, the generic skills of communication and teamwork were often not well developed. This situation is echoed in Australia, where communication skills and the ability to work with others were among the attributes identified (McInnis, Hartley and Anderson, 2000) as falling short of employers' expectations.

With this in mind we asked departments to estimate the percentage of total student time spent on physics-specific and more generic knowledge and skills. The results are shown in Figure 7 and indicate that just under half of a student's total time is spent on acquiring knowledge and understanding of physics concepts, models and theories. Problem solving ranks second with 15-20% of the total time, written communication is next with almost 10% and the remaining generic skills all are 5% or lower. Interestingly the top two skills have slightly higher assessment weighting than student time spent on them. Conversely, the generic skills all have slightly lower assessment weighting than student time spent on them. This possibly suggests the relative difficulties in assessing generic skills as opposed to physics knowledge. Overall however, these results show that departments are incorporating generic skills into the learning outcomes of a physics undergraduate degree.

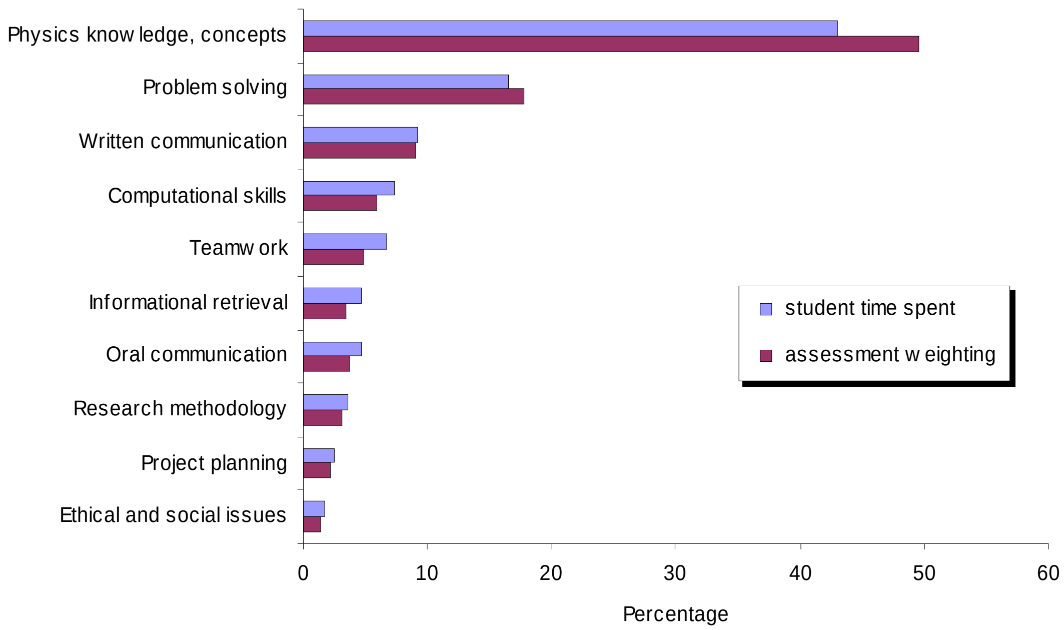

Figure 7. Prioritisation of specific and generic skills as a percentage of the mainstream physics degree program, averaged over all departments.

Laboratories Experimental laboratories increasingly have to compete for time in undergraduate physics curricula with less resource-intensive components. Laboratory facilities are expensive to maintain and Figure 2 shows that maintaining, let alone upgrading, them is a complex challenge faced by many departments. The issue for departments is to ensure that the level of resources spent on experimental laboratories is sufficient to provide the basic experimental physics grounding and not compromise the integrity of the physics major.

While cuts have been made to undergraduate laboratory programs over the last decade, Figure 8 shows that they still make up a substantial proportion of the total contact hours of the physics programs at all years. At over half of all institutions the students spend between a third and a half of their contact time in the physics laboratory. Only three departments report that time spent in laboratories accounts for less than 20%. The high proportion of time spent in laboratories at most institutions is not surprising given that most physics departments regard the quality of the laboratory program and equipment as a learning and teaching strength.

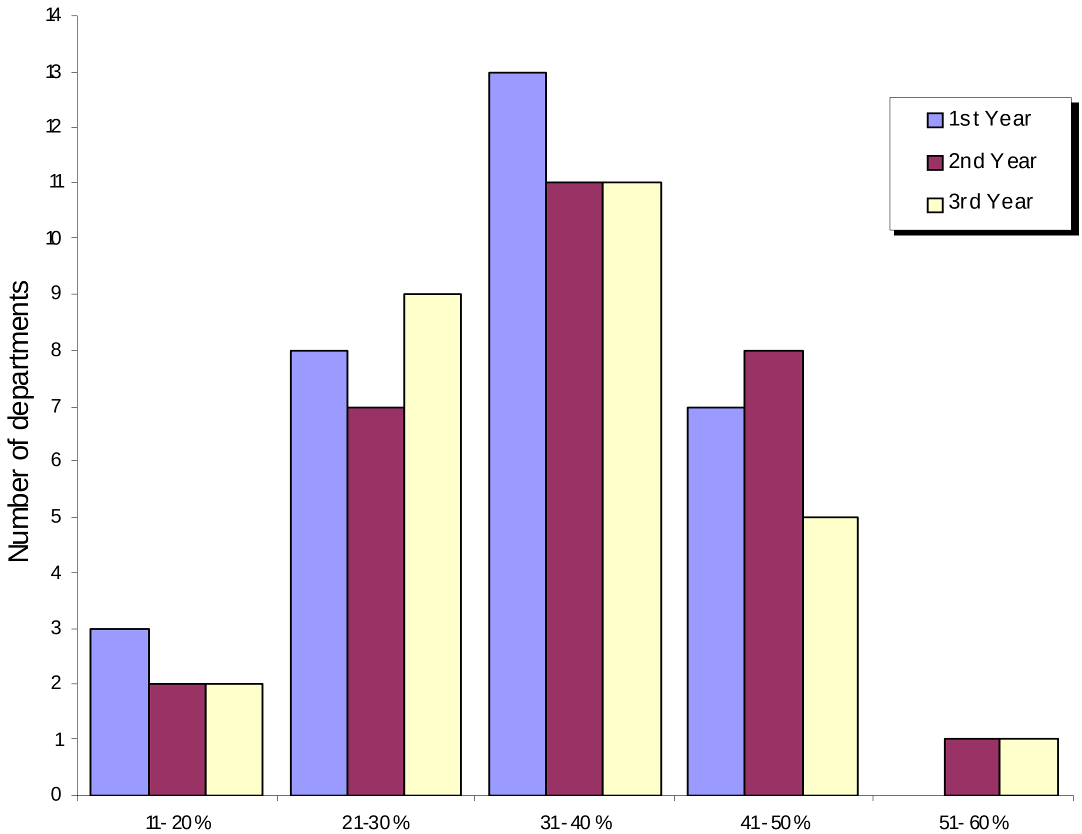

Figure 8. Fraction of students' contact time in physics spent in experimental laboratories.

Learning physics

Student experiences and expectations have changed significantly in the last decade. In order to teach more effectively, departments need to know who their students are and what motivates them to study physics. Two significant factors affecting current students are increases in time spent working whilst studying and the new technologies used in learning and teaching.

Work and study Almost a third of tertiary science students currently work more than 10 hours per week, in addition to being full time students (Vickers, Lamb and Hinkley, 2003). Many academics express concern over students' ability to meet their course requirements at the same time as maintaining employment, and working up to 20 hours a week does appear to increase the chance of dropping out (Vickers, Lamb and Hinkley, 2003). On the other hand, it may well be in a student's interest to work part time, if they can do so without adversely affecting their studies, as employers rate skills such as time management, communication skills, and team work more highly than subject specific knowledge (McInnis, Hartley and Anderson, 2000).

New modes of learning and teaching The way in which students now access and use information is very different to previous generations. On the whole, the current generation take for granted rapid, easy access to information and expect it to available 24 hours a day. Today's students want lectures and other face-to-face classes to be supplemented with material and activities online. Learning and teaching in higher education is changing drastically with such changes.

In the last decade, physics departments report that they have attempted to incorporate new teaching methods, with varying degrees of success. This has happened partly in response to the observed limitations on effective student learning with the traditional teaching framework of lecture, tutorial and laboratory, and partly in an effort to try new approaches. Increasingly, these traditional modes of instruction are being redesigned to become more learner orientated. Whilst many innovative methods of teaching physics have been developed, there have been few, if any, that have been widely adopted to supplement the traditional framework. This is mainly due to the high cost, both financial and in terms of human resources, of developing and maintaining such innovations.

In the questionnaire, departments were asked, *'Aside from traditional lectures, laboratories and tutorials, have you introduced new modes of learning and teaching?'* The most common new directions are shown in Figure 9. Departments have widely adopted online resources, primarily as a course delivery tool and depository for extra course material, but with online assessment becoming increasingly widespread.

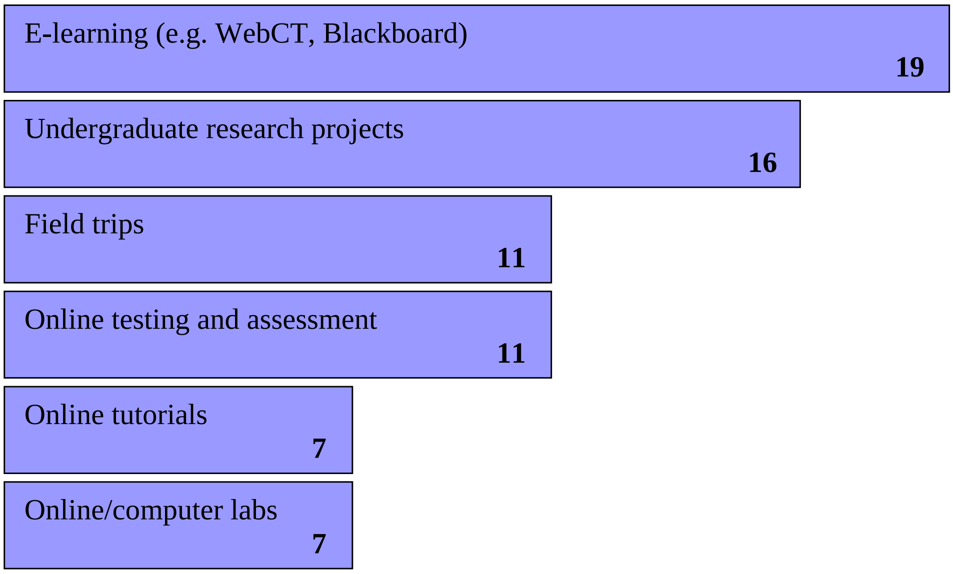

Figure 9. New modes of learning and teaching introduced in Australian physics departments.

The use of electronic delivery and learning support is quite widespread. Over half of all physics departments have introduced e-learning in some form (with WebCT and Blackboard the most common platforms), and just under half report that they will introduce online delivery of subjects in the near future. A third of departments have online testing and assessment. Just under a quarter of physics departments offer online tutorials and online/computer laboratories.

Student views After establishing the various directions physics departments are taking in learning and teaching, the study sought the opinions of those who are directly affected, the currently enrolled students. More than 100 physics students (in first and third years from nine institutions and in both mainstream and service courses) took part in focus groups, delving into various aspects of their undergraduate physics studies.

When asked, '*What features of your physics studies has most helped your learning?*', the majority of students highlighted similar features. Regular assessment, assignments and worked examples/practice problems in both lectures and tutorials were seen as the key features in learning physics content. That students rate these features highly suggests that they recognise that the formal course assessment (traditional examinations) will be the main measure of their learning of physics. A secondary feature identified by the majority of students was the availability of resources and course notes, both handed out in class and available on the web. This would appear to indicate that students are concerned about having confidence over the content of a course and want as much material as possible.

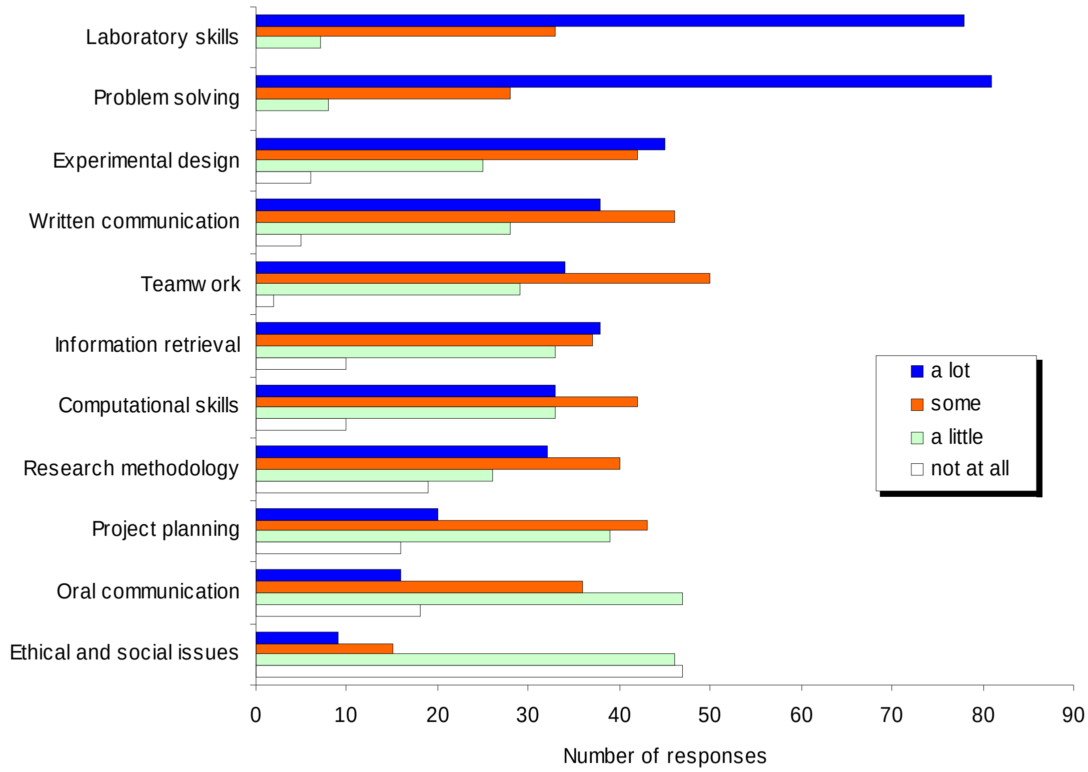

Figure 10. Students' ranking of skills developed or used in their undergraduate physics studies.

Students were asked to rank the time spent developing various generic skills during their university physics studies (Figure 10). Laboratory skills and problem solving emerged as the two dominant skills acquired, which is consistent with the departmental view given in an earlier section. Overall the two sets of rankings are almost identical, with only minor reordering of categories at the lower end of the scale. Although our sample sizes were small, we did not find any significant differences between the rankings provided by the various groups (first and third year students, students taking a physics major and service students).

Implications for physics learning and teaching

The shifting environment of the Australian university sector has forced physics departments to change rapidly. This has required the development of considered visions for the future, something that in the past many departments have been guilty of neglecting. The attitude that *everyone can see why physics is important* can no longer be taken a priori and the continued existence of physics departments no longer taken for granted. Indeed, not all departments have survived and some look very different to traditional physics departments. Put simply, physics departments have had to meet the challenges of the economic drive.

No single (or indeed simple) solution has been identified to combat the problem of how to continually improve the quality of teaching in the face of diminished financial resources. The many challenges facing physics departments have resulted in efforts that have been innovative, taken advantage of new technologies, and focussed more on student learning rather than producing fundamental change.

The versatility of physics departments is underpinned by the fact that *physics is important* to a wide variety of disciplines. While there have been losses in certain areas of service teaching, new alliances have been forged. Both service and multidisciplinary teaching is increasingly being valued and supported.

In general, students report that they learn best in ways which physics learning and teaching has traditionally emphasised, including regular assessment, effective feedback and small group activities and projects. But circumstances have changed over the last decade with students working more and needing more flexibility in the delivery of content. In addition, real reductions in government funding per student place has increased cost pressures. Physics departments have responded by greatly expanding e-learning activities, albeit more for flexible delivery and perceived cost savings rather than clear pedagogical reasons. This study indicated that e-learning has largely been limited to providing ready access to resources and some online diagnostics and testing, rather than revolutionising the learning and teaching process.

A key question that was not asked in this study but requires further investigation is to what degree innovative methods improve learning outcomes.

Conclusion

This study of undergraduate physics education has provided an extremely important vehicle for the physics education research community and all identified physics departments in Australia to communicate on physics education issues. It prompted widespread review and reflection on how physics is being taught by physics departments and allowed for a comprehensive 'state of the nation' report on the current health and practices of undergraduate physics with recommendations for the future (Sharma et al., 2005). Good learning and teaching approaches were identified and examples of these were disseminated to the Australian physics community (Mendez *et al*. 2005). The views of graduates and employers have also informed our understanding of the usefulness of a physics degree (Sharma et al., 2008). We are continuing to explore aspects of this study to better understand some of the important issues raised. With the knowledge gained and networks created through this continuing study, the university physics community and other stakeholders are better able to confront the challenges and take advantage of opportunities in a rapidly changing environment.

Acknowledgements

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References

Biggs, J. (2003). *Teaching for Quality Learning at University,* (2nd Edition) London: Open University Press, ISBN-10: 0335211682.

de Laeter, J., Jennings, P. & Putt, G. (2005). Physics enrolments in Australian and New Zealand Universities 2000–2005. *Australian Physicist*, **42**, 115–23.

Hersh, R.H. (2005). What Does College Teach? It's time to put an end to 'faith-based' acceptance of higher education's quality. *Atlantic Monthly*, **296**(4), 140-143. Retrieved May 13th, 2009 from http://www.theatlantic.com/doc/200511/measuring-college-quality

Hilborn, R.C., Howes, R.H. & Krane, K.S. (2003). SPIN-UP/TYC: American Association of Physics Teachers: *Strategic Programs for Innovations in Undergraduate Physics at Two-Year Colleges*. Retrieved May 13th, 2009 from http://www.aapt.org/Projects/ntfup.cfm

Hodges, I. (2002). It is vital that Imperial is run as a university business. *The Independent, Education*. Retrieved May 13th, 2009 from http://www.independent.co.uk/news/education/higher/it-is-vital-that-imperial-is-run-as-a-university-business-656419.html

Institute of Physics *Inquiry into Undergraduate Physics*. (2001). Retrieved May 13th, 2009 from http://www.iop.org/activity/policy/Projects/Archive/page_6337.html

Jagger, N., Davis, S., Lain, D., Sinclair, E. & Sinclair, T. (2001). *Employers Views of Postgraduate Physicists*, Report by the Institute for Employment Studies to the Engineering and Physical Sciences Research Council. Retrieved May 13th, 2009 from http://www.employment-studies.co.uk/pdflibrary/1417phys.pdf

Jaschik, S. (2006). Fresh Approach to Accountability. *Inside Higher Ed*, 3 April. Retrieved May 13th, 2009 from http://insidehighered.com/news/2006/04/03/nasulgc

Learning Outcomes and Curriculum Development in Physics. (2005). Retrieved May 13th, 2009 from http://www.physics.usyd.edu.au/super/AUTC/

Marginson, S. (2007). *The 2007 edition of Education at a Glance: Where does Australia sit in the OECD Comparison?* University of Melbourne, Centre for the Study of Higher Education Seminar series: 'Ideas and Issues in Higher Education'.

Mazur, E. (1997). *Peer Instruction: A User's Manual*, Upper Saddle River, New Jersey: Prentice Hall.

McDermott, L. C. & Redish, E. F. (1999). Resource Letter: PER-1: Physics Education Research, *American Journal of Physics*, **67**(9), 755-767.

Mendez, A., Feteris, S., Kirkup, L., Livett, M., Low, D., Merchant, A., Mills, D., Pollard, J., Raynor, A., Sharma, M., Swan, G., Wilson, K. & Zadnik, M. (2005). *Snapshots - Good Learning and Teaching in Physics in Australian Universities.* Retrieved May 13th, 2009 from http://www.physics.usyd.edu.au/super/AUTC/

McInnis, C., Hartley, R. & Anderson, M. (2000). *What Did You Do With Your Science Degree?* Occasional Paper for the Australian Council of Deans of Science (ACDS). Retrieved May 13th, 2009 from http://www.acds.edu.au/whydoa.htm

McInnis, C., James, R. & McNaught, C. (1995). *First Year on Campus: Diversity in the initial experiences of Australian undergraduates*. A Commissioned Project of the Committee for the Advancement of University Teaching, Centre for the Study of Higher Education, University of Melbourne.

Sharma, M.D., Mills, D., Mendez, A. & Pollard, J. (2005). *Learning Outcomes and Curriculum Development in Physics*, A Report Commissioned by the Australian Universities Teaching Committee and the Carrick Institute for Learning and Teaching in Higher Education. Retrieved May 13th, 2009 from http://www.physics.usyd.edu.au/super/AUTC/

Sharma, M.D., Pollard, J., Mendez, A., Mills, D., O'Byrne, J., Scott, D., Hagon, S., Gribble, J., Kirkup, L., Livett, M., Low, D., Merchant, A., Rayner, A., Swan, G., Zadnik, M. & Zealey, W. (2008). What does a physics undergraduate education give you? A perspective from Australian physics. *European Journal of Physics*, **29**(1), 59-72. Retrieved May 13th, 2009 from http://www.iop.org/EJ/toc/0143-0807/29/1

Ramsden, P. & Martin, E. (1996). Recognition of Good University Teaching: Policies from an Australian Study. *Studies in Higher Education*, **21**(3), 299-315.

Vickers, M., Lamb, S. & Hinkley, J. (2003). *Student Workers in High School and Beyond: The Effects of Part-Time Employment on Participation in Education, Training and Work*, LSAY Research Report No 30. Retrieved May 13th, 2009 from http://www.acer.edu.au/documents/LSAY_lsay30.pdf