

# Carrick Institute for Learning and Teaching in Higher Education

## ***Learning Outcomes and Curriculum Development in Physics Project***

### **Final Report, December 2005**

**Project Leaders** – David Mills (Monash), Manjula Sharma (Sydney)

**Project Officer** – Alberto Mendez (Sydney)

**Steering Committee** – *Chairs*: Adrian Lee (UNSW) and Alan Robson (Western Australia, early 2004),

Brian James (Sydney), Les Kirkup (UTS),

Michelle Livett (Melbourne), Richard Newbury (UNSW),

Judith Pollard (Adelaide), Mike Prosser (UK), Marjan Zadnik (Curtin)

**Project Team Members** – Anna Binnie (UTS), Maria Cunningham (UNSW), Susan Feteris (Monash),

David Low (UNSW@ADFA), Alex Merchant (RMIT),

John O'Byrne (Sydney), Anton Rayner (Queensland), Michele Scoufis (UNSW),

Geoff Swan (Edith Cowan), Kate Wilson (ANU), William Zealey (Wollongong)

**Expert Advisors Panel** – Richard Gunstone (Monash), Barry Muddle (Monash),

John O'Connor (Newcastle), John Prescott (Adelaide)

## **Summary**

The major objectives of the project were to evaluate the learning and teaching of physics in Australian tertiary institutions and to encourage and facilitate good learning and teaching by sharing good practices and by strengthening the network of tertiary physics educators.

Our two main publications present the 2004 evaluation of learning and teaching, and provide resources through the *Snapshots* booklet (2005). They reach the decision makers and every-day practitioners of the tertiary physics community. Two workshops of national scope and other conference presentations have enhanced the capabilities of a substantial number of individuals and departments. Australia has gained expertise in developing and evaluating learning and teaching quality through the project team and others immediately associated with it.

To sustain this momentum and to ensure that tertiary physics education contributes effectively in Australia's future, the project team recommends that the Australian physics community (physics departments, Australian Institute of Physics, and the Heads of Physics Departments group) explore strategies and invest in:

- Identifying and making effective use of existing successful practices and resources, such as laboratory experiments, through further publications such as *Snapshots* or online.
- Instilling the need to understand teaching and learning issues amongst the new generation of physics educators by being more proactive in the scholarship of teaching through further workshops and conferences.
- Investigating where physics graduates go, what they do and what are their capabilities in order to provide an adequate supply of physics graduates into further study and the workforce.

## Overview of the Project

The project has been undertaken by a team largely drawn from the Physics Education Group of the Australian Institute of Physics (AIP-PEG). The team comprises representatives from 13 tertiary institutions, a dedicated project officer and a group of expert advisors.

The major objective of 2004 was to evaluate the learning and teaching of physics in Australian tertiary institutions. An extensive, open-response questionnaire on issues for mainstream, multidisciplinary and service teaching, changes, challenges and responses, new initiatives and strengths, the interface with employment, staffing and teacher training, was sent to all 34 groups or departments who teach tertiary physics in Australia. The response was exceptionally positive with a 100% completion rate for the 14-page questionnaire. At nine selected departments, interviews with heads of departments and leaders of academic programs, and focus groups of students (at four different levels of their physics education), were conducted to gauge how curricula are responding to change, what approaches are effective, how departments plan for teaching, and what they expect and need for their future. Expert advisors were consulted regarding employment and their insights on current and possible future directions. The findings are presented in the published Report (see Section on Outcomes of the Project point 2).

The major objectives of 2005 were to strengthen the network of tertiary physics educators and to disseminate good learning and teaching practices. In early 2005, the project team consulted Heads of Departments and participants at the Australian Institute of Physics Congress. In light of their responses and the findings from 2004, a plan for a National Workshop was drawn up. The workshop focused on areas identified as priorities and was held at the University of Sydney in September. In parallel with preparations for the workshop, graduate and employer interviews were carried out and further data on good learning and teaching practices were collected from departments, having commenced both these processes in 2004. A discussion paper on the graduate and employer experiences has been prepared. A selection of good practices drawn from many departments and covering diverse features has been compiled into a booklet, *Snapshots – Good Learning and Teaching in Physics in Australian Universities*. Its unique style should make it useful and interesting for tertiary physics educators.

This report documents outcomes of the project, in particular the National Workshop and the *Snapshots* publication, as well as ongoing outcomes. All reports, documents and other information can be found on the project website at:

<http://www.physics.usyd.edu.au/super/AUTC/>

## Outcomes of the Project

The project has achieved its aims over the 2004 and 2005 funding period. We first present the outcomes achieved in chronological order before expanding on some key outcomes.

1. A paper was presented at the national UniServe Science *Scholarly Inquiry into Science Teaching and Learning* Symposium in Sydney (October 2004):
  - A. Mendez, M.D. Sharma, B. James, D. Mills, J. Pollard, L. Kirkup, M. Livett, R. Newbury, M. Zadnik and M. Prosser, *AUTC Physics Project: Learning Outcomes and Curriculum Development*, Proceedings of the “Scholarly Inquiry in Flexible Science Teaching and Learning” Symposium, p24-29, ISBN: 1-86487-665-4. Presenter Dr M.D. Sharma.
2. A 64 page Report on 2004 findings was published and sent to all tertiary physics departments and other interested parties (including deans where appropriate via the physics heads):

M.D. Sharma, D. Mills, A. Mendez, and J. Pollard, **Eds**, *Learning Outcomes and Curriculum Development in Physics: A Report on Tertiary Physics Teaching and Learning in Australia commissioned by the AUTC*, February 2005, ISBN: 0-7326-2063-5.

3. A presentation was given to the Heads of Physics Departments at their meeting in Canberra in January 2005. Twenty Australian physics departments (or groups) were represented. The following points were noted during the ensuing discussions:
  - Departments have responded to constant change by adopting many new strategies. It has been difficult to sustain quality teaching and learning as well as research programs.
  - The question of how departments can advance teaching and learning was discussed. Proposals such as sharing of teaching resources (for example manuals and equipment) have arisen in the past but have not eventuated, and any mechanism such as a common database would require substantial time and funding.
  - Graduates who went into industry could be surveyed to find out what physics has done for their career - something easily done for chemistry but not as easily for physics. There could be sharing in areas of careers advice as many students enter physics programs without having any definite career in mind. The AIP and physics alumni could be partners in this process.
  - The question was asked if students coming into physics programs are adequately prepared for their studies. Every state in Australia has a different high school physics syllabus, which means that there is a large variation in entry skill level.
  - It was noted that students are doing a lot more part time work than in the past to support themselves while carrying out their studies.

The Heads of Department meeting could have a significant role to play in future learning and teaching improvements at a national level, possibly in a partnership with a working group from the AIP Physics Education Group.

4. The Australian Institute of Physics held its biennial Congress in Canberra (February 2005), with 950 registrants. Tertiary Physics Education was a strong stream within the Congress, and the following related directly to the Project:
  - a. A keynote address in the Physics Education stream overviewed the 2004 key findings. Attended by heads from many departments, it was standing room only:

B. James, L. Kirkup, M. Livett, A. Mendez, D. Mills, R. Newbury, J. Pollard, M. Prosser, M. Sharma, M. Zadnik, *Key Findings from the National Physics Project on Learning and Teaching*, 16<sup>th</sup> Australian Institute of Physics National Congress Proceedings, p230, ISBN: 0-9598064-8-2. Presenter: Dr M. Livett.
  - b. Three concurrent workshops (on catering to a diverse student body, effective use of educational research and new technologies, and resources for staff development) attracted some 80 people, including many younger academics:

B. James, L. Kirkup, M. Livett, A. Mendez, D. Mills, R. Newbury, J. Pollard, M. Prosser, M. Sharma, M. Zadnik, *Implications of the National Physics Project for Teaching and Learning – a Workshop*, 16<sup>th</sup> Australian Institute of Physics National Congress Proceedings, p230, ISBN: 0-9598064-8-2.
  - c. An attractive broadsheet (A3) summary of the highlights of the 2004 findings was distributed during the conference to the majority of tertiary academic

attendees. With the title *Challenges, Responses, and Strategic New Directions*, it summarised key aspects of importance to physics educators and was aimed at raising awareness of the project, and of learning and teaching issues in general.

- d. The Physics Education stream had a much higher profile than previous years and the Physics Education Group attracted some 30 new members.
5. A colloquium was given to the School of Engineering Physics at the University of Wollongong, presenting the findings of the 2004 stage of the project. Presenter Mr A. Mendez.
6. A presentation was given at the Higher Education and Research Development Society of Australia, HERDSA, in Sydney (July 2005):

L. Kirkup, M. Livett, A. Mendez, D. Mills, R. Newbury, J. Pollard, M. Sharma, M. Zadnik, *The Evolution of the Teaching and Learning of Physics in Australian Universities*, Presenter Dr M.D. Sharma.
7. An invited talk was given at the 2004 American Association of Physics Teacher Summer Meeting, a major annual event for tertiary physics educators.

M. D. Sharma, *Teaching and learning of physics in Australian universities*, AAPT Summer Meeting, Sacramento, USA, Announcer, 34, pp 175.
8. A paper was presented at the International Conference on Physics Education, ICPE, in Delhi (August 2005):

L. Kirkup, M. Livett, A. Mendez, D. Mills, R. Newbury, J. Pollard, M. Sharma, M. Zadnik, *Learning Outcomes and Curriculum Development in Physics: A project evaluating tertiary physics learning and teaching in Australia*, ICPE 2005 “World View on Physics Education: Focusing on Change” Programme & Abstracts, p104. Presenter Mr A. Mendez.
9. A National Workshop on Tertiary Physics Learning and Teaching was held in late September, focusing on areas identified as priorities (see below and the Appendix).
10. A booklet, *Snapshots Good Learning and Teaching in Physics in Australian Universities*, draws together an inspiring set of good physics learning and teaching practices from across Australia. It is in print and will be sent to all tertiary physics educators and departments (see below).
11. The Physics Education Group of the Australian Institute of Physics has been substantially strengthened during the course of this Project (see below).
12. A resources web-page has been set up so that academics can readily access the best sources for physics education research based teaching and learning materials. This is anticipated to continue to develop over time under the direction of the Physics Education Group.
13. A discussion paper has been prepared on questions relating to employment of bachelors graduates based on interviews with recent graduates and employers, for consideration by Heads of Departments and the AIP, and for later publication (see below):

M. Cunningham, L. Kirkup, M. Livett, D. Low, A. Mendez, A. Merchant, D. Mills, J. O’Byrne, J. Pollard, A. Rayner, M. D. Sharma, G. Swan, M. Zadnik, W. Zealey, December 2005, *Australian Physics Bachelors and Honours Graduates in Industry: Where are they and how well prepared are they?*

In the Proposal for 2005 we planned to hold workshops in the larger capital cities. This was not carried out to the extent originally envisaged, as better alternatives were available. When the 2005 Proposal was prepared in September 2004 we (and most others) did not anticipate the huge attendance at the AIP Congress in Canberra in early 2005. The strong support for the Physics Education stream at the Congress was another factor, with attendance from 80 to 110+ (in the

previous congress in 2002 this stream attracted a core group of up to 30 plus a similar number of others coming to any given talk). In our planning it also became apparent that the Einstein (International) Year of Physics was going to fill much of the year with additional events, so that finding times for additional state-based workshops, and people who were able to commit, would be difficult. The main factor for not conducting state-based workshops was that with the Congress and the National Workshop, physics academics had two excellent opportunities for workshoping and networking over an extended period with a large group of like-minded people. This was considered to have much higher impact than one or two presenters going to a central destination to meet with a small group for a short time.

### **National Workshop**

On 28 September 2005, a day-long National Workshop on *Key Issues in Learning and Teaching in Undergraduate Physics* was held at the University of Sydney. Presenters for the workshop were drawn from across physics departments, showcasing a range of innovative and successful practices. The full programme can be found in the Appendix. The focus was on areas identified as priorities by the 2004 findings, including:

- catering for diverse student backgrounds
- interactive strategies for large classes
- effective assessment, on-line learning
- careers and graduate attributes
- effective sharing of knowledge/resources across institutions

There was good national representation, with 45 delegates from 23 institutions attending (including four departmental heads). It provided an invaluable opportunity for academics to come together to discuss learning and teaching issues, and to be exposed to the variety of good approaches which are being implemented at institutions across the country. The success of the workshop was due to the wholehearted participation and the enthusiasm of all present. A substantial fraction of the participants stayed the next day for the *First Year Experience* day of the Uniserve Science Symposium which included two workshops for physics educators run by members of the Project team. We believe the workshop assisted in the process of equipping a generation of younger academics and strengthened the network across the tertiary Australian physics community.

### **Snapshot - Good Practices Booklet**

In the first half of 2005, further data were collected from physics departments, with the aim of cataloguing (in a booklet publication) the range of good learning and teaching practices currently taking place across Australian institutions. During the second half of 2005 a selection was made from the abundant raw material collected and twelve themes to be featured were chosen. The finished *Snapshots* booklet is at the printers and will be widely distributed in all physics departments and to appropriate staff across institutions. Featuring some 40 examples in addition to overview articles, we expect it to have a positive impact.

### **Networking - The Physics Education Group of the Australian Institute of Physics**

This two-year project has strengthened the Physics Education Group (PEG) of the Australian Institute of Physics in achieving its goals of understanding and improving the learning and teaching of physics in Australian universities. The group (which formally came into existence in 1998) has previously only been active at the AIP Congresses. The strength of the Physics Education programme at the AIP National Congress was one obvious manifestation. The community of practice is now stronger, with approximately 100 active members, including most importantly younger academics some of whom are taking leadership roles. The Group now has

proven approaches for moving forward, and has a nucleus with expertise in developing and evaluating learning and teaching quality.

## **Graduate Capabilities and Employer Satisfaction**

In order to ascertain how well physics courses prepared graduates for the workplace, work on interviews with physics graduates and their employers commenced in 2004 and continued into the early part of 2005. The process of locating graduates who had completed a three-year (Pass) or four-year (Honours) degree and had gone directly into the workplace (without further study) proved difficult since such graduates are surprisingly rare. This was not expected by the Project team and was a revelation to some departments. We estimate that only a few percent (less than 5% and possibly closer to 3%) of those undertaking 3<sup>rd</sup> year physics go into science-related work with a single degree.

A total of 15 interviews were conducted with employees and graduates and gave a consistent picture. One of the goals of the original project brief for 2005 was to provide an “analysis of the relationship between course design and indicators such as enrolment and employment trends, graduate satisfaction and graduate employability.” While the number of interviews could have been expanded, it became clear that from any one institution there was no way of readily getting a representative sample of such graduates. Hence our analysis does not provide indicators at the level of course offerings from individual departments. It does however look at the relevant factors for Australian physics graduate employability on a broader scale.

A discussion paper has been prepared for consideration by the Australian tertiary physics community, to be circulated to the AIP and to Heads of Physics Departments (with a request for discussion at their next meeting in March 2006). It contains the outcomes of the interviews and the factors relating to the small number of three or four year graduates entering the workforce. The paper raises broader questions such as whether there is a need for more diversity in the upper-level curriculum, and how the physics community recognises and promotes the hidden roles of physics graduates in jobs which are not labelled ‘physics’.

## **Future Directions**

Our published report on the project’s findings from 2004 made numerous recommendations. For the “Future Directions” of Australian tertiary physics (Chapter 8 of the report) we focussed on how we may deal with four key issues: obtaining better support for tertiary physics education; developing a more effective structure involving the Physics Education Group of the AIP, the AIP and the Heads of Physics Departments group; effective means of sharing resources; and prioritising the areas for needed resources. Our interactions with Heads of Departments and tertiary physics academics during 2005 reinforce those recommendations.

To sustain the current momentum in improving learning and teaching, specific activities of an ongoing nature which are possible for 2006 are:

- workshops on good practice case-studies at the AIP Congress, December 2006;
- a physics discipline day in conjunction with the UniServe Science conference as in 2005;
- publications in *Australian Physics* and the International Conference on Physics Education Newsletter.

A more thorough investigation of the interface of employment and tertiary physics education is, we believe, a matter of priority. Where do physics graduates go? What do they do? What are their key capabilities? How do we provide an adequate supply of physics graduates for both further study and the workforce? With the support of all physics departments, it would be feasible, for example, to obtain a picture of what happens to one year’s group of third year and honours students. The broader questions as raised in the discussion paper will require much more thought across the widest group of stakeholders in Australian physics, science and technology.

A second future project would be an extensive collation of resources which have been tried and tested in Australia. Our experience with *Snapshots* booklet and the targeted resources prepared for the National Workshop, demonstrates that this is achievable when the goals are clearly defined. Such resources could be available through a specific physics “clearing-house” either as ready-to-use packages (such as the CUTSD *Workshop Physics Tutorial* materials), or in summary form (such as in the *Snapshots* booklet). Such a project would require substantial effort and funding both for the scoping phase (What sorts of materials? What is already available globally? What types of peer review processes? What forms of cooperation? Who are the owners and stakeholders - departments, the AIP, possibly UniServe Science and The Carrick Institute?) and its implementation.

A critical question is who will maintain the momentum and take new initiatives? A working group of the AIP Physics Education Group would be one possibility, or a working group selected and given a mandate by the AIP, AIP-PEG and the Physics Heads of Departments meeting.

The directions taken by The Carrick Institute for Learning and Teaching in Higher Education will be important. We look forward to seeing how a project such as those described above, which arises from the teaching-learning coal-face within a discipline, will engage with the Institute’s priorities.

## **Finances**

A financial report will be presented for the 2005 stage of the project by the end of January 2006 as required. Funding from The Carrick Institute for 2005 was \$85000. Expenses are lower than anticipated for the National Workshop as several presenters did not claim costs, and for travel and accommodation as project members used other funds to attend the AIP Congress. Salary costs for the Project Officer are higher than originally budgeted as in essence the project has required about 23 months actual work. The Project Officer is working to the end of 2005 with leave accrued in 2005 paid out at the conclusion of his contract. The savings mentioned above have in effect been used to better achieve the project’s targets.

## **Acknowledgements**

The project team thanks the Australian Universities Teaching Committee and The Carrick Institute for Learning and Teaching in Higher Education for funding support in 2004-2005, and the support of their staff. The project’s achievements are the direct result of the many contributions made by Physics departments through their Heads, contact persons, academic programme leaders and other staff. We take this opportunity to extend thanks to the whole team for their efforts and especially for those who took leading roles, presented at conferences, wrote or edited publications and responded to requests to tackle the tasks which arose. The team is grateful for the conscientious and capable effort of Alberto Mendez as Project Officer.

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David Mills    and          Manjula Sharma  
on behalf of the Project Team

23 December 2005

## **Appendix.: National Workshop Programme**

<b>Key Issues in Learning and Teaching in Undergraduate Physics – A National Workshop</b> University of Sydney Wednesday 28 September 2005	
Morning session (08:45 – 14:00) in the main Physics building (Lecture Theatre 5, 1 <sup>st</sup> floor)	
08:45 – 09:10	Welcome and introduction to the workshop
09:10 – 09:30  <b>Showcase Topic 1</b>	<b>Promotion of Careers in Physics: A Challenge!</b> <i>Bill Zealey</i> University physics is changing. In response to the need to become more relevant departments have introduced applied (and in some cases almost vocational) degree programs. These “market driven” changes lead us to review the following questions: <ul style="list-style-type: none"> <li>• How do we market our degrees to students?</li> <li>• What careers do we prepare them for?</li> <li>• What careers do physics graduates seek?</li> <li>• How far should we interact with industry in adapting our degrees to their needs?</li> </ul>
09:30 – 09:50  <b>Showcase Topic 2</b>	<b>How (and Where) to get Physics Education Research Published</b> <i>Manjula Sharma</i> Getting physics education work published and considered as research publications raises questions such as: <ul style="list-style-type: none"> <li>• What constitutes physics education research?</li> <li>• How can teaching developments projects generate publishable results?</li> <li>• What journals are appropriate and/or available?</li> </ul> Answers to these and other questions from the audience will be explored.
09:50 – 10:10  <b>Showcase Topic 3</b>	<b>Graduate Attributes, do we Explicitly Address them in our Curricula?</b> <i>David Mills</i> Surveys of physics graduates in the workplace show conclusively that problem solving skills and communication skills rank higher than specific knowledge. The emphasis of our curricula is often the reverse. We will look at some approaches to help achieve the best outcomes for our graduates.
10:10 – 10:30  <b>Showcase Topic 4</b>	<b>Effective Strategies for Interactive Large Group Teaching and Learning</b> <i>Ian Johnston</i> Between 1999 and 2003, the School of Physics at the University of Sydney carried out several different trials to assess the teaching effectiveness of Interactive Lecture Demonstrations (ILDs) in first year physics courses. These investigations involved several different lecturers, and some coordination with a physics department at a university in Thailand. Treating this as a case study in teaching intervention, the speaker will offer some personal reflections on wider questions thrown up by the experience.



10:30 - 10:50	Address by <i>Adrian Lee</i> - Chair of AUTC Physics Project Steering Committee - Pro Vice Chancellor UNSW (Education and Quality Improvement)
10:50 - 11:20	Morning Tea
11:20 - 12:50	<b>Physics Tutors and Laboratory Demonstrators: Issues Involved in Teaching Sessional Staff to Teach Students</b> <i>Susan Feteris and Marjan Zadnik</i> Students' closest contacts are with tutors and demonstrators – usually sessional staff. It is critical that these staff are effective teachers who encourage and support student learning, are familiar with academic and safety obligations, and can advise on academic matters. How do we develop such professionalism in a time poor environment? Issues, strategies and materials from two well-established tutor and laboratory demonstrator workshop programs will be discussed and demonstrated. Participants will leave with ideas, tools and materials to enhance their own programs.
12:50 - 14:00	Lunch
Afternoon session (14:00 – 18:00) in the Eastern Avenue Complex (Rooms 404, 405 and 406)	
14:00 - 15:30	<b>Undergraduate Projects</b> Discussion on the variety of ways undergraduate projects are utilised, the features they share and their effectiveness as a mode of learning. Good practices from QUT and WA will be featured. <i>Moderators: Manjula Sharma and Les Kirkup</i>  <b>Assessment/Feedback</b> Exploring the ways to use both as effective learning tools (also include graduate attributes). <i>Moderators: Michelle Livett, David Low, Judith Pollard and Kate Wilson</i>
15:30 - 16:00	Afternoon Tea
16:00 - 17:30	<b>On-line Learning Tools</b> Exploration of the range, benefits and limitations of web based tools. MasteringPhysics and WebCT quizzes will be featured. <i>Moderators: Alex Merchant, John O'Byrne and Geoff Swan</i>  <b>Diverse Student Backgrounds (Service Teaching)</b> Exploring ways to cater for and retain students with vastly differing backgrounds. Good practices from New England, La Trobe and UTS will be featured. <i>Moderators: David Mills and Manjula Sharma</i>
17:30 - 18:00	Recap and consolidation
18:00 onwards	Dinner at a nearby restaurant for those interested!