Physics Education for Australia

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How is the context and nature of physics education in Australian universities changing?
What factors are constraining staff and departments in providing quality teaching and learning?
How can we best share good practices so that physics education strengthens, is sustained and grows?

The context, funding and project team

The project was commissioned in 2004 by the Australian Universities Teaching Commission (AUTC) with the aim of encouraging innovative and effective approaches to teaching and learning in physics that are appropriate within the current context. Its successor, the Carrick Institute for Learning and Teaching in Higher Education, continued funding the project in 2005 with the aims of sharing good practices and strengthening networks.

The current context for physics education in universities is indeed complex with quite dramatic changes occurring during the last decade within most institutions. These include changes to the nature and expectations of the student body, changes in staffing, infrastructure and resource allocations in departments, changes in employer expectations and emerging multidisciplinary areas. In response to these changes, departments have identified and employed various strategies to provide high quality physics teaching and learning. Individual, departmental and collective experiences captured in this project provide opportunities for sharing understandings of the current context and advancing the teaching and learning of physics in Australian universities in effective and efficient ways. Recent major studies in the USA and UK have informed and complemented this project.

The project was carried out by physics academics from a broad cross section of Australian universities, under the leadership of Dr David Mills (Monash University) and Dr Manjula Sharma (University of Sydney) and with the support of the Project Officer, Alberto Mendez. The project team consisted of academics drawn largely from the Physics Education Group (PEG) of the Australian Institute of Physics (AIP). A task force was established to investigate each of the five major themes:

- **Mainstream physics courses.** Leader: Richard Newbury (University of New South Wales). This task force investigated the types of mainstream physics courses being taught, and why and how they are evolving. Trends in curricula, course delivery, new directions for teaching and learning, and the teaching/research nexus were explored. Issues such as the role of the undergraduate laboratory program, and good teaching and learning practices were also considered.

- **Service courses and multidisciplinary teaching.** Leader: Les Kirkup (University of Technology, Sydney). This task force explored the nature of, and trends in, service and multidisciplinary teaching. Key questions included: how are departments adapting to the changing needs of client departments; how have curricula evolved and how have the degrees being offered changed? Issues such as student preparedness and high school physics teacher training were also considered.

- **Student satisfaction.** Leader: Marjan Zadnik (Curtin University of Technology). This task force investigated student satisfaction, attitudes, views and backgrounds. The influence of student gender ratios, work commitments, and motivation on the teaching and learning of physics were explored. A key question considered was: how do changes in high school teaching shape decisions made by departments?

- **Employer satisfaction.** Leader: Judith Pollard (University of Adelaide). This task force investigated employer satisfaction, needs and involvement in course development. Graduate destinations and trends in employment were explored. Issues such as graduate attributes and skills, and the employer-department interface were considered.

- **Academic staff.** Leader: Michelle Livett (University of Melbourne). This task force investigated current practices in recruitment, support for teaching and learning initiatives and academic staff development. Current practices in new staff induction, and sustaining good teaching and learning practices were explored. Issues such as tutor and sessional staff training and support, mentoring, and recognition of teaching achievements were considered.
The project aimed to capture the essence of physics teaching and learning in Australian universities, and map the path forward based on collective experiences, both successful and not so successful.

Data collection
The identification of 'Physics Departments' has become less straightforward in the past few years, as reduction in staff numbers and organisational restructures have occurred in many universities. The term 'department' has been used generically in this project to indicate a group of academics engaged in research and undergraduate teaching of physics. The project identified 34 Australian universities in 2004 whose teaching ranged from the archetypal Bachelor of Science degree with a major in physics to relatively new degrees such as nanotechnology, photonics and security technology, with most departments also teaching service or multidisciplinary physics subjects.

Several different procedures were used to gather data. These included accessing web pages, seeking questionnaire responses from Physics departments, engaging in focus group discussions with students, and conducting interviews with individual department heads, curriculum co-ordinators, physics graduates and employers.

At an early stage, the project team recognised the importance of engaging physics departments in the data gathering processes. To this end a departmental AUTC Physics Project Contact Person was nominated for each department. The level of commitment displayed by these people has been very much appreciated by the project team and underpins a significant fraction of the findings of the project.

Thanks to the cooperation of members of all Physics departments, information was gathered about student numbers and physics courses at all 34 of the universities where physics is taught. More detailed data was obtained through interviews and focus groups at nine departments, selected to represent each state and capture the diverse types of departments.

Stage 1 report highlights
The major findings of the project were presented in the Stage 1 Report “Learning Outcomes and Curriculum Development in Physics”. Copies of this report have been distributed to each participating university. Each major section of the report gave rise to a series of recommendation, some of which are discussed below. The Executive Summary, containing the complete set of recommendations can be downloaded from www.physics.usyd.edu.au/super/AUTC/.
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The changing nature of students: implications for teaching

Investigation of the changing nature of physics students gave rise to several recommendations related to appropriate teaching. Most departments have identified changes in the background of students commencing physics studies, and have adapted in a range of ways, as shown in Figure 1 (from ref 3, Figure 5.2).

Recommendation 3.1:
That physics staff include in the curriculum learning activities that cater for a variety of learning styles and contemporary technology.

Recommendation 3.2:
That physics staff recognise and value diversity of student background, such as previous physics and maths studies, work experience, gender and cultural background in designing the curriculum.

Recommendation 3.3:
That physics staff acknowledge the competing demands on students’ time, including part time work, when designing learning and assessment tasks.

Recommendation 3.4:
That physics staff communicate their expectations of students clearly and explicitly.

Recommendation 3.5:
That physics departments involve younger academics and consult students in teaching and learning decision-making.

Figure 1: Categorised and quantified questionnaire responses to “B7. Please make any general comments regarding student backgrounds entering physics, including effect of changes to high school physics or mathematics. How has your own department adapted to these changes?”
Learning and teaching
The project sought answers to the questions “How are our students learning?” and “How are we teaching?” In the face of a decline in staff numbers and in laboratory and information technology (IT) facilities on the one hand, and poorer preparation of our students on the other, departments are responding by restructuring the curriculum and laboratories, changing their subject offerings and introducing new learning activities and new technology.

The effectiveness of these responses was evaluated in part by asking students which activities are most helpful to their learning. The most common responses included interaction with helpful and knowledgeable lecturers, tutors and demonstrators, regular assessment, and worked examples in class. Recommendations related to this section of the report arise from an awareness that the goal of improving learning and teaching quality in Australian physics departments depends on teaching staff having a better awareness of approaches and resources which have been evaluated and demonstrated to be pedagogically sound and efficient in terms of human and financial resources.

Recommendation 6.1:
That Physics departments and the AIP through the Physics Education Group support and undertake research into the effectiveness of learning and teaching strategies such as the use of IT and e-learning, the contexts and benefits of undergraduate research projects, and opportunities for optimising our investment in and commitment to laboratory experience.

Recommendation 6.2:
That the Carrick Institute provide support for further research into effective physics learning and teaching in the Australian context, with particular attention to Generation Y.

Recommendation 6.3:
That heads of physics departments and the Australian Institute of Physics cooperate in establishing improved mechanisms for promoting and sharing good practice, such as supporting academic exchange visits and contributing to UniServe Science.

Recommendation 6.4:
That the AUIC project team identify academic staff with an interest in physics for biological and medical sciences, and encourage them to collaborate in the production of common course materials appropriate for the Australian context.
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**Staffing challenges and responses**

Forums for discussing teaching and learning issues are available within Physics departments to a variable extent. Figure 3 shows the extent to which staff are supported in this endeavour. Recommendations in this section of the report recognise the importance of providing opportunities for sessional and full-time staff to have access to appropriate training, and opportunities to develop teaching innovations.

<table>
<thead>
<tr>
<th>Well supported (resources, financially, exceptions, etc)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Encouraged by department to further teaching and learning</td>
</tr>
<tr>
<td>Teaching is a consideration for promotion</td>
</tr>
<tr>
<td>Awards for teaching innovation</td>
</tr>
<tr>
<td>Dependent on availability of time</td>
</tr>
<tr>
<td>No special support</td>
</tr>
<tr>
<td>Staff use study leave to further teaching and learning</td>
</tr>
<tr>
<td>Dependent on funding</td>
</tr>
<tr>
<td>Badly supported</td>
</tr>
<tr>
<td>Encouraged if they can raise funds to support it</td>
</tr>
<tr>
<td>Present embargo on all course and program redevelopment</td>
</tr>
</tbody>
</table>

![Figure 3: Categorised and quantified questionnaire responses to H2. How does your department (or faculty) support staff interested in curriculum enhancement and investigating issues related to teaching and learning of physics? (from ref 3, Figure 7.2)](image)

**Recommendation 7.1:**
That departments provide time, and resources for staff who contribute substantially to innovative and quality teaching, recognise their contribution to retaining students, and support their promotion based on their teaching.

**Recommendation 7.2:**
That Heads of departments and institutions ensure academic staff appointments address teaching capabilities alongside research, that new appointees have a good induction to teaching and learning, and that ongoing support is provided for physics-specific teaching and learning practices.

**Recommendation 7.3:**
That departments value the contribution that demonstrating, tutoring and sessional staff have on students and should ensure adequate training and support, both in terms of physics content and teaching and learning issues.

**Recommendation 7.4:**
That the AUTC project team in Stage 2 highlight and disseminate good practices and available resources for demonstrator and tutor training.
Future directions
Several recommendations were made with a view to facilitating the implementation of earlier recommendations. As indicated in the section on dissemination, some of these are already being put into effect.

**Recommendation 8.1:**
That the Heads of departments and the AIP consider means by which they can more effectively support tertiary physics education in Australia, including obtaining strategic government funding and strengthening the AIP Accreditation guidelines.

**Recommendation 8.2:**
That the Physics Education Group of the AIP play a more prominent role as a network which provides effective mechanisms for promoting and sharing good practice. To achieve this, it should invite a wider membership, have representatives from all departments and support for its activities from Heads of physics departments and the Australian Institute of Physics.

**Recommendation 8.3:**
That the AUTC project team, Heads of departments, and the AIP cooperate in establishing an effective means of sharing teaching resources and providing a database containing evaluations of and advice regarding resources.

**Recommendation 8.4:**
That the AUTC project team and Heads of departments work together to prioritise areas for evaluation or provision of teaching resources, with special attention to resources adapted to an Australian context.

Dissemination
In 2005, the project team concentrated on disseminating findings, strengthening networking amongst the higher education physics community and developing strategies for sharing good practices. The major initiatives in this stage of the project were conference and workshop presentations, the publication of Snapshots and development of the web page.

**AIP Congress**
The Australian Institute of Physics Congress in Canberra, January/February 2005 marked both the International Year of Physics and the launch of our efforts to engage with the physics community. The AUTC project made a presentation to the HoDs meeting, had a keynote address delivered to an audience with barely any standing room and presented Workshops in the PEG sessions which attracted some 80 people.

**National Workshop - Physics one-day conference**
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 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). The workshop 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. Many of the participants stayed 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. The workshop assisted in the process of equipping a generation of younger academics and strengthened the network across the tertiary Australian physics community.

**Snapshots of good practice** - “Snapshot – Good Learning and Teaching in Physics” provides descriptions of the range of good learning and teaching practices currently taking place across Australian institutions. Twelve themes are featured:
- Large Classes
- Service Teaching
- Context-Centred Teaching
- Laboratory Work
- Small Class Activities–Tutorials
- Undergraduate Projects
- Online Learning
- Distance Learning
- Tutor/Demonstrator Training
- Interface to Employment
- Communication Skills
- Teamwork

The booklet features some 40 examples in addition to overview articles and has been widely distributed in physics departments and learning and teaching centres at all participating universities.

**Project web pages**
A resources web-page has been set up so that academics can readily access the best sources for physics education research.
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based teaching and learning materials. It includes links to teaching resources which have been developed or implemented at Australian universities, and to Australian publications related to research in Physics education. This will continue to develop over time under the direction of the Physics Education Group.

Networking − the Physics Educations Group of the AIP

This two-year project has enhanced the ability of the Physics Education Group (PEG) of the Australian Institute of Physics to achieve 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; it is particularly encouraging that many newly active members are 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.

The future of Physics Education

This article gives an overview of the project, its recommendations and some of its more important findings. More complete information is available in the Stage 1 report¹ and the Snapshots booklet² distributed to all physics departments, and via the project web pages³ at www.physics.usyd.edu.au/super/AUTC/. The very important matter of the capabilities of our graduates, their employment destinations and the degree of employer satisfaction will be the subject of an article in a future edition of Australian Physics.

Acknowledgements

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References