

# **AUTC Physics Project: Learning outcomes and curriculum development**

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## **Abstract**

The Australian Universities Teaching Committee is funding a project to investigate the learning outcomes and curriculum development in physics at Australian universities. The project aims to map current practices and future directions in the broad areas of curriculum relating to service/multidisciplinary teaching and majors, employer satisfaction and industry involvement, and student satisfaction. A questionnaire has been administered with 85% return to date from the 34 physics departments or groups in Australian universities. In this paper we present the study design and initial results which include consideration of challenges faced by departments with respect to teaching and learning, departmental strengths and the development of new courses.

## **Introduction**

Concern has been expressed nationally and internationally about the strategic directions taken by physics departments to ensure a healthy future for the discipline of physics. This concern encompasses many elements including the role of physics departments in nurturing highly capable graduates destined to play major roles in research and industry and providing the essential practical and quantitative underpinning to many disciplines including those of engineering and the biosciences. These concerns have motivated major studies in undergraduate physics in both the USA (AAPT 2003) and the UK (IOP 2001), which provide some comparative materials for this study.

In 2003, the Australian Universities Teaching Committee (AUTC) provided a project brief for an investigation of learning outcomes and curriculum development in physics in Australian Universities (AUTC web site, 2003). The majority of the successful project team belongs to an existing network, the Physics Education Group of the Australian Institute of Physics, (AIP-PEG), with expertise in the teaching and learning of physics in Australian universities. The project team comprises a Steering Committee with working party leaders who have responsibilities for specific tasks, a wider group of working party members, and a group of expert advisors. Representing 13 universities, the project team provides excellent coverage for obtaining an accurate and representative picture of the teaching and learning of physics in Australian universities. In this paper we present the study design, initial results from the questionnaire and main features emerging from the study so far.

In the first phase of the project, we identified key areas and designed a questionnaire. In the second phase the questionnaire was administered in universities teaching physics, and further data is to be obtained by in-depth interviews and focus groups. In the third phase, we will develop criteria and identify good and innovative practices. The final phase is to complete the analysis and present a report, due in December 2004.

## Aims of the project

The project brief was to evaluate how undergraduate physics teaching and learning is responding to a number of substantial changes, in particular the new requirements of multidisciplinary areas; the increasing role of the new technologies and of globalisation; the nature of the student body and of student expectations; graduate employment destinations and the requirements of employers; the relationships between Physics and Engineering, and Physics and Biological Sciences; the role of academic physicists in preparing teachers for physics in schools. As tangible outcomes which will benefit all stakeholders, we aim to identify, evaluate and communicate good practices in Australian undergraduate physics education.

## Methodology

There are 34 Australian universities with a group of academics teaching physics. For convenience we refer to such a group as a ‘department’ even though several groups do not carry this title. All such groups in the 34 universities have agreed to participate in the project and each has nominated a contact person. Privacy arrangements require that institutions and individuals are not identified except when a department agrees to have a good-practice example show-cased.

We are using the 7 key areas listed below as a map for our data collection and analysis.

- 1: Overview of Teaching and Learning in the context of each department’s environment
- 2: Teaching and Learning practices for physics majors, service and multidisciplinary teaching.
- 3: Student satisfaction, expectations and attitudes.
- 4: Relations with industry and employers, and graduate employability.
- 5: Staff development and successful Teaching and Learning practices.
- 6: Trends in student numbers and strategies for staffing in the face of declining budgets
- 7: School teacher education and in-service.

Data collection method	Key areas						
	1	2	3	4	5	6	7
Questionnaire	×	×		×	×		×
DEST data						×	
CEQ data			×				
Head of department interview	×	×		×	×		
Teaching programs interview	×	×	×	×	×	×	
Focus group with first year students		×	×		×		
Focus group with third year students		×	×		×		
Focus group with postgraduate students		×	×	×	×		
Interviews with graduates			×	×	×		
Interviews with employers				×			

Table 1: A summary of the data collection methods and the key areas that are addressed.

Table 1 summarises the data collection methods and how they address the key areas. The questionnaire has been designed and distributed to each of the 34 departments, requesting responses by the department Head or a designated representative. The questionnaire design was based on the recognition that each department has a unique teaching and learning situation, including its institutional structure, degree programs, and student cohorts, so that the local context will often affect how a question is interpreted. For this reason the questionnaire is almost entirely free-form. It focuses on the current situation and those changes in the past 5 years which impact on the present, with opportunity to comment on future directions. The data from the questionnaire is being used to provide an overview of the teaching and learning across all Australian universities, and to identify

trends, themes, and successful practices. Data analysis and interpretation occurs as data is gathered, at times influencing further research questions.

In August-September 2004 we will conduct in-depth studies at nine selected institutions, comprising an interview with the department's head, an interview with the person responsible for academic programs in the department, and focus groups with first year, third year, and postgraduate students. Interviews with graduates in the work force and employers are also planned.

Two external sources of data will be considered. The Department of Science Education and Training (DEST) in Australia maintains enrolment statistics for Australian universities, and it is hoped that these may be used to show trends in student numbers. However there are recognised difficulties in using such data, as reported by the Australian Council of Deans of Science (Dobson 2003). The Course Experience Questionnaire (CEQ) is administered to university graduates within six months of their graduation, and may be used to study trends and comparisons for key area 3. There are concerns about CEQ's relatively low return rate and the inclusion of astronomy and materials science with physics in the 'Physical Sciences' category.

## **Analysis and results**

In this paper we present preliminary results giving an overview of the teaching and learning of physics, some features that recur across institutions and some aspects of the broader context for teaching and learning. The data from 29 questionnaires that have been returned (to July) are analysed using categories generated from the free form responses. If a response to a question has multiple comments then it is placed in more than one category. The categories are then synthesised into three themes: changes in human resources, infrastructure and resources, and teaching profile. The latter can be subdivided into changes in student numbers, changes in offerings of subjects, courses or degree programs and changes in teaching quality.

### **Overview**

We now present the initial analysis of some questions for key area 1, overview of teaching and learning at a departmental level, and related questions from other key areas. The reported features vary greatly between departments, and within one department there are often multiple causes for changes in teaching profile. Six institutions reported that they do not offer a physics major; the remaining 23 have physics to 3<sup>rd</sup> year. Five departments indicated that the focus of their physics major was theoretical physics. The remainder have some combination of experimental, applied and specialist research areas or a broad range of areas. In the analysis below, the frequency of each comment and its theme is indicated in brackets.

### ***What challenges has your department faced in physics teaching and learning in the last 3-5 years?***

The dominant comments were:

- declining staff numbers and downsizing departments (18: human resources)
- laboratory and IT facilities and staff downgraded (12: infrastructure and resources)
- attracting students, drop in student numbers (11: teaching profile: changes in student numbers)
- loss of (or conflicts with) service teaching (11: teaching profile: changes in offerings)

### ***How has your department responded to the challenges mentioned above?***

The most frequent comments were:

- restructuring of curricula and/or labs (11: teaching profile: changes in teaching quality)
- introduction of new technology e.g. WebCT (10: teaching profile: changes in teaching quality)
- introduction of new majors or degrees e.g. photonics, nanotechnology (9: teaching profile: changes in offerings)

### ***What directions will the teaching and learning in your department take in the near future?***

The most frequent comments were:

- more new majors or courses (15: teaching profile: changes in offerings)
- more on-line delivery of subjects (12: teaching profile: changes in teaching quality)
- more service and/or multidisciplinary teaching (8: teaching profile: changes in offerings)

### ***What are the strengths of the teaching and learning in your department?***

The most frequent comments were:

- dedicated experienced staff (13: human resources),
- high quality research area specialisation (12: teaching profile: changes in teaching quality)
- staff-student interactions (11: teaching profile: changes in teaching quality)

These responses help form an overview of these 29 departments. The challenges are dominated by human resources and by changes in the teaching profile generally resulting from loss of service teaching. Departments have responded to the challenges predominantly by introducing new subjects/degrees or rationalising existing ones and changing teaching quality by exploring different ways of teaching and learning physics. Four departments commented on the conflict between teaching and research, but for other departments, the teaching-research nexus has generated new teaching opportunities.

Future directions are dominated by the introduction of new subjects or degrees. There were six comments regarding sharing of service teaching and four comments about sharing of subjects with other institutions. We note diverging strategies such as small-group interactive learning for in-depth learning (3 comments) versus reduction of contact time with students for staffing or budgetary reasons (3 comments).

Dedicated and experienced staff and the quality of teaching are viewed as strengths by approximately half the responding departments. However increased efforts to recruit students were mentioned only twice and attempts to improve retention only once. While such an absence may not be significant in free-form responses, the low response indicates that it is rarely considered in the sweep of teaching and learning issues.

### **Recurrent features**

There is a complex interplay between the categories and themes across all questions. The following features in the theme of teaching profile emerge from questions in key areas 1 (overview), 2 (teaching offered) and 5 (staff and teaching development).

### ***Use of undergraduate research/project work either in teaching labs or with research groups***

The coupling of research expertise of a department with the teaching and learning is being explored in various ways with undergraduate research projects being a popular option.

### ***The importance of laboratory work***

Two-thirds of the responding departments had over 30% of students' contact time in physics spent in laboratory in year 1, and over half of the departments had registered over 30% time in laboratory in year 3. In response to a question asking how the physics education community could work cooperatively, five institutions requested assistance with experimental work.

### ***Use of Information Technology and web based teaching and learning resources***

Online teaching and learning resources specifically mentioned are e-learning using WebCT, Blackboard, online testing and assessment, online tutorials, online-computer labs, and mixed media lectures. Suggestions of ways in which the physics education community could help departments included a database of physics resources, on-line subjects, on-line showcase of Physics in Australia and updated videos.

### ***Changes in assessment practices***

Departments are exploring alternative means of assessment with less focus on final exams. The assessment of undergraduate research/project is interesting in that it can be coupled with generic skills. Eleven comments were made that physics majors from their programs were characterised by generic scientific skills, raising interest in how these skills are evaluated and assessed.

### **Broader Context for Teaching and Learning**

Several features arising from the questionnaire deserve special mention.

### ***Students' preparation for undergraduate physics is a concern***

This issue was explored by asking 'Please make any general comments regarding student backgrounds entering physics ...'. In response, 15 departments indicated that students were less prepared in mathematics, 9 that students were less prepared in physics, 2 that students have better background in physics and 4 that students were poor at understanding/applying physics concepts.

### ***Industry and employer partners are participating in a variety of ways***

Advisory committees (8 departments), required industry experience (7 departments), curriculum design (5 departments) and assessment (3 departments) are the common inputs from external partners. Only one department indicated that industry ties constitute a strength of their teaching and learning, although four departments said that teaching by outside experts is a strength. Nine departments have indicated that new degrees have been introduced in response to changing perceptions of employment opportunities. Four institutions say that they obtain formal (built-in) feedback from employers, while seven say that they have informal feedback.

### ***Service teaching continues as a major factor in teaching effort and funding***

Eight departments report that more than 50% of their departmental income is from service and multidisciplinary teaching, while seven report figures between 20 to 50%. Service teaching for engineering has been reduced substantially (14 departments). Six departments have service teaching branching into new areas. Five departments specifically refer to losses in service teaching resulting in reduced funding and loss of staff. Six departments indicate that client departments have increased input into curriculum development. Only two departments report that service teaching is poorly supported; others indicate good support or the same level of support as mainstream subjects.

### ***Specialist and double degree programs are increasingly popular***

About half the departments indicate that such programs are successful although five say that student numbers are small. Areas being developed include nanoscience, photonics, biophysics, medical physics, meteorology, energy studies, sports mechanics and security technology.

### ***Support for teaching and learning development***

In a majority of departments, good support is provided for curriculum enhancement and teaching and learning issues. In 16 departments, this is through resources, financial support, encouragement, promotion, awards and study leave. Five departments indicate that no special support is provided, two that such activities are poorly supported and one has an embargo on course redevelopment.

### ***Mechanisms for training new staff***

Nineteen departments mention university generic teaching courses, seven mention mentoring by senior staff and six have departmental training courses. Three departments say there is a requirement for a certificate in higher education teaching and two that staff are expected to learn as they go.

## **Discussion and Implications**

The number of bachelors degrees awarded in physics in the US declined steadily in the 1990's (AAPT, 2003). In Australia the number of third year physics students reached an all-time peak in

1993 and steadily declined until 2001, although a strong rise occurred in 2002 (Jennings, 2003). In the UK, numbers of graduates in physics have held steady, though the number of departments offering physics has decreased (IOP, 2001). The UK and Australia are following contrasting paths in order to meet the challenge of enduring and flourishing in a difficult and increasingly competitive environment. In the UK, some physics departments have expanded dramatically, focussing largely on the 'core business' of teaching physics to physics majors. By contrast, results so far in our study indicate that service teaching and new multidisciplinary degrees, such as nanotechnology, are vital ingredients of the physics teaching being carried out in Australian universities. This study supports the notion that reliance on service teaching places smaller physics departments in Australia at risk when, for example, faculties of engineering revise their undergraduate courses.

There is evidence in our preliminary results that physics departments are exploring new areas for service teaching and new degree programs. This is happening in parallel with, or as a result of declining staff numbers and reduced teaching in tradition areas, such as service teaching to engineers. These findings confirm the impressions gained through discussions with physics academics in Australian universities. On one hand we note the exploration of more new alliances to introduce new subjects and degrees, and on the other hand improving teaching quality, e.g. by introducing research projects and online delivery. There is a recognition by departments that shared resources should be beneficial, yet on the other hand the sharing to date has been informal and diffuse, without much recognisable gain from specifically funded projects.

The US study identified that no single element guarantees a thriving physics department, and found that the common elements for success were a) a well-developed curriculum and strongly supportive student-staff interactions, b) the support of a large fraction of the department in developing the undergraduate curriculum, c) strong and sustained leadership identifying strategies suited to their local environment (AAPT 2003). Hence this overview of teaching and learning is important in establishing the nature of the local environment. This will be essential for identifying and effectively sharing good practices as the project progress to exploring in depth the successful approaches taken in various local situations.

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