

LEARNING OUTCOMES AND CURRICULUM DEVELOPMENT IN PHYSICS: A PROJECT EVALUATING TERTIARY PHYSICS LEARNING AND TEACHING IN AUSTRALIA

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A project was commissioned in 2003 by the Australian Universities Teaching Commission (AUTC) titled "Learning Outcomes and Curriculum Development in Physics". Its aims were to evaluate a wide range of learning and teaching practices and innovation in tertiary physics across Australia, in the context of such factors as: the response to new requirements of multidisciplinary areas; the increasing role of new technologies; the changing nature of the student body and of student expectations; the change in graduate destinations, and employer satisfaction; and the preparation of both secondary and tertiary physics teachers. The project was conducted by a team representing 13 universities, drawn largely from the Physics Education Group of the Australian Institute of Physics. A selection of important findings from the first stage of the project is here presented. The full report can be obtained from <http://www.physics.usyd.edu.au/super/AUTC/>.

1 Introduction

The first stage of the project was completed in 2004 and sought to survey the current state of physics learning and teaching in tertiary institutions and possible future directions. A 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 completed by all of the 34 groups or departments who teach tertiary physics in Australia. Its format was largely open-response to enable a clear description by each department. At nine selected departments, interviews with heads of departments and leaders of academic programs, and focus groups of students, 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. The results presented in this paper have been drawn exclusively from the collected responses.

2 The Departments' View

1.1. Main Teaching and Learning Challenges

The questionnaire to all participating physics departments asked "What challenges has your department faced in physics teaching and learning in the last 3-5 years?" The dominant response categories are presented in Figure 1.



Figure 1: The dominant challenges to teaching and learning for Australian physics departments. The number of departments citing each categorised response is shown.

Overwhelmingly, the greatest challenge has been the decline in staff numbers. Ranked below this is the downgrading of laboratory, IT facilities and staff, the difficulties in attracting students to physics and the loss of, or conflicts with, service teaching. These are all serious challenges, they are mostly issues that are driven by economic factors, and which have a direct impact upon good practice in teaching and learning.

The restructuring of courses and degrees, the weaker physics and mathematics background of the student intake and the increased load on teaching staff are also cited as important challenges. Reduction in funding appears explicitly alongside increased administration and the changing teaching environment. An increase in lecture class sizes may not appear to be, of itself, a factor impacting directly upon teaching and learning, but it certainly imposes an additional burden of work on academic staff (feedback, assessment, marking) and course administration.

1.2. Responses to Challenges

Looking at some of the ways in which departments have responded to current challenges the leading five responses are: restructuring of the curriculum and laboratories; the introduction of new majors and degrees; the introduction of new technology (e.g. WebCT); rationalisation and/or reduction of subjects; and shared service teaching.

Each of these is broadly an issue in teaching and learning but further examination is needed to ascertain whether or not these responses are to the benefit or the detriment of good teaching and learning. Restructuring of the curriculum might be a good thing whilst restructuring of laboratories hints at economies which are often negative.

In the same vein, WebCT/Blackboard is all a la mode and can be a very positive thing if implemented properly, offering flexibility of delivery and imaginative teaching with access to multimedia enhancement and judiciously chosen information sources. On the down side, if for example it is used primarily to save money in replacement of expensive staff for 'live' tutorials, it is obviously a step in the wrong direction. More research is needed to evaluate the impact of restructuring and electronic/web delivery.

The loss of service teaching, particularly for engineering, has been substantial in many departments, though this is partly offset by emerging areas including the biomedical and health sciences, and physics for agricultural industries.

1.3. New Directions in Teaching and Learning

When questioned about the introduction of new teaching methods, both current provisions and those planned for introduction in the near future, departments report that the use of electronic delivery and learning support is quite widespread. Over half of the physics departments have introduced e-learning in some form (e.g. WebCT) and just under half will introduce on-line delivery of subjects in the near future. Just under a quarter of physics departments offer on-line tutorials and on-line/computer laboratories. A third of departments have on-line testing and assessment.

A handful of departments plan to introduce further on-line assessment in the near future, and a similar number of departments will also reduce contact time with students. The inference might be that on-line methods are replacing 'live' contact time.

Almost half of the 34 departments offer undergraduate research projects and a third have field trips as part of the curriculum.

Only comparatively small numbers of departments currently have workshop tutorials, active learning laboratories or mixed media lectures so that these particular newer modes of teaching are in evidence but are far from being widely implemented at present, and are likely to be at first year level. This situation is unlikely to change dramatically in the short term. Only three departments report that there will be emphasis on small group/interactive learning in the near future.

Whilst this might be viewed as disappointing it is, nevertheless, unsurprising when viewed against the background of the 'rearguard' action being fought by many

departments, particularly the smaller ones. Adventurous and attractive new approaches to teaching require more staff time, more resources and a greater level of financial support, all things which departments do not have at their disposal. Particular note should be made of the enormous effort, in the recent past (and anticipated in the future), in introducing new majors, degrees and subjects.

1.4. *Laboratory Programs in Undergraduate Physics*

While cuts have been made to undergraduate laboratory programs over the last decade, they still make up a substantial element of the total contact hours of the undergraduate physics curriculum. At a quarter of all departments in first to third year, 20-30% of total contact time is spent in laboratories. At roughly a third of all departments, the time spent in laboratory physics in first to third year, is in the range 30-40% of total contact time. A smaller number of institutions report that time spent in the laboratory is up to half of the total course contact time.

It is for third year laboratory which the majority of departments with full laboratory programs report particular strength. However, there are also strengths and some newer features identified in the first year laboratories by some departments. These include teamwork, continuous review of the experimental programme by a dedicated laboratory director, and computer-based pre-laboratories and data analysis.

Precise ratios of teaching personnel to students in laboratories are difficult to gauge from available data but typical numbers in first year would be 15-20 students per demonstrator (a graduate student or sessional teacher) with one academic staff member supervising.

1.5. *Teaching / Research Nexus*

Anecdotal evidence suggests that there is at least some degree of conflict for most full time academics in juggling teaching and research priorities. There is a widespread belief, or perhaps an acceptance, that career advancement is determined largely by research performance (funding success, publications and so on).

With smaller academic staff numbers in departments, increasing institutional focus on fiscal considerations and accountability (leading to additional administrative load), the balancing act that academics must perform vis-a-vis teaching and research priorities is made more difficult. If courses remain static, it must surely stifle innovation in teaching and learning and imaginative and sustainable response to changing student needs. So what is the evidence from departments that, under current constraints, there is a healthy and positive teaching-research nexus in departments?

The range of core lecture courses/electives and the course content reflects directly the research interests of academic staff at many institutions. More than half of departments report that subjects are offered in the specialist research areas of the staff.

Approximately one-third of departments have students undertaking a research project within a research group. A smaller but significant number of departments report that examples from departmental research are discussed in lectures.

1.6. Graduate Attributes and Skills

The emphasis placed on specific physics knowledge, understanding and skills in the undergraduate physics degree is justified by the extent to which these attributes are used by graduates proceeding to further study, and also by graduates moving into employment, particularly the large fraction in professional Science positions. However, there is increasing awareness that generic skills are also important.

In the questionnaire, departments were asked to indicate the percentage of time spent by students on generic skills and the assessment percentage assigned to each skill category, as well as to physics knowledge and concepts. Figure 2 shows the mean for each of the ten given categories as measured by time spent by students and assessment weighting.

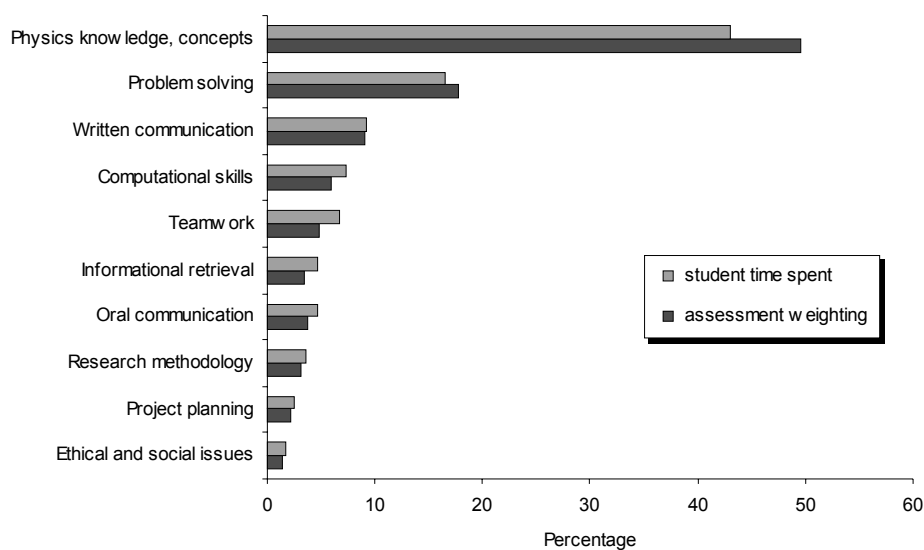


Figure 2: Departmental prioritisation of skills developed by students in undergraduate physics studies, as measured by time spent by students and assessment weighting, averaged over all departments.

Problem solving and physics knowledge carry a slightly higher average assessment weighting than is justified by time spent. These two aspects account for nearly 70% (on average) of the assessment weighting, and there is a relatively low emphasis given to the other skills. This stands in contrast with the typical demands of the workplace and what employers expect from physics graduates. Studies in Australia [1] and the USA [2] have shown that for most positions taken by physics graduates (except as a physics teacher),

being a physics graduate is not a requirement. Whilst problem solving skills are high on the list for all industry sectors, the relatively low use of specific physics knowledge is strongly notable.

A UK study of physics postgraduates [3] noted that, while they ranked high on problem solving, the generic skills of communication and team-work were often not well developed. This situation is repeated in Australia, where written and oral communication skills and the ability to work with others were among the attributes identified by as falling short of employers' expectations.

3 The Students' View

3.1 How are they Learning?

Student perspective on current approaches to teaching and learning was obtained through focus groups. At each of the nine selected university four focus groups were conducted to sample the full student cohort range: first year physics majors, first year service students, third year physics majors and postgraduates. Students were asked:

In response to "What features of your physics studies has most helped your learning?", regular assessment, quizzes, assignments and worked examples/practice problems in both lectures and tutorials feature strongly for first year students. It is not surprising that first years rate these features highly as they will recognise the style of the formal course assessment (traditional examinations) that they are likely to be measured against. A second feature apparent in the responses of first years is the importance students place on handouts in lectures, notes on the web and helpful/talented/interesting lecturers. This would appear to indicate that students are concerned about having confidence over the content of a course (perhaps 'trusting' handouts or notes on the web more than lecture notes they record themselves). One can see, therefore, students find regular assessment and feedback helpful. They also appreciate good staff/student communication and helpful lecturers and they are able to recognise good lecturing.

Interestingly, however, responses from third year students highlight similar features. Third year students also identify regular assessment, problem solving and examples in lectures/tutorials and good study guides as the features that most helped their learning. A secondary feature identified is the availability of web-based resources.

Overall, the student perspective on the features of their studies that most helped them learn does not uncover any startling findings. If anything, these responses might be characterised as indicating a rather conservative attitude to the mechanisms of studying physics.

3.2 What are they Learning?

Responses to “What do you think are the valuable skills and knowledge you have gained from your physics studies?” show clear evidence for perceived enhancement of problem solving, analytical skills and logic across all focus group categories from first year service students to third year. Analytical and problem solving skills would be identified by most academics as one of the foundation skills which should be enhanced through the students’ physics studies. An understanding of fundamentals and ‘description of everyday things’ together with application of basic physics concepts (to other disciplines) also features very strongly in responses from first and third year students, again showing that students recognise that the objective of connecting physics to real and practical issues is being realised.

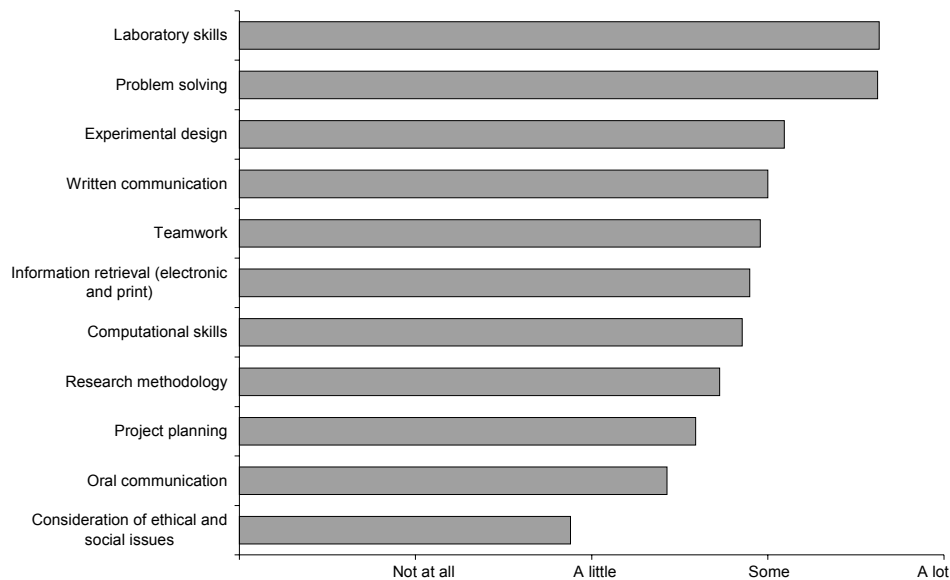


Figure 3: Students’ ranking of skills developed or used in their undergraduate physics studies.

In addition to the above open-ended question students were given a table of graduate attributes and skills and asked to specify the level (from *not at all* to *a lot*) to which they believed certain skills had been developed or used in their undergraduate physics studies. The results are presented in Figure 3. Nearly all of these students believe that they have acquired ‘some’ or ‘a lot’ of skills in relation to problem solving, laboratory and experimental design. They are least sure about possessing skills in project planning, oral communication and social and ethical, issues.

4 Comparison of Expectations

Comparing the perceptions of departments, students and employers, there is a gap between the skills developed in an undergraduate physics education and the desired skills for a physics graduate in the workplace. Oral communication is one area where improvement may be made with appropriate learning activities, though the additional resources to support these improvements may not always be available.

From interviews with heads of departments, it was evident that consideration was being given to integrating generic skills into their physics degree programs with an “overall goal to produce a rounded physics graduate”. This was particularly the case at the younger universities and those heavily involved in servicing other disciplines. In many cases the integration was driven by university policy.

The selected departments were also asked how students were made aware of the subject and program objectives. Common mechanisms for communication of objectives relating to generic skills were by subject handouts and first year orientation programs. However, there was a general feeling that students were often unaware of, or lost sight of, these objectives.

5 Conclusion

We have described the first stage of the project and presented a subset of the results, providing a clear picture of where physics learning and teaching in Australian tertiary institutions currently stands. Although departments have faced a multitude of challenges over the past decade, they have proved both adaptable and resilient, and have strived to provide students with the best learning and teaching environment possible. More information on the project and the complete report can be found at our website: <http://www.physics.usyd.edu.au/super/AUTC/>.

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