



## Teaching physics to non-physics majors: models extant in Australian universities

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***Abstract:** A key goal of the study entitled ‘Forging new directions in physics education at Australian universities’ granted funding by the Carrick Institute for Learning and Teaching in Higher Education is to review service teaching being carried out nationally in Australian universities and to articulate what constitutes excellence in physics service teaching or, more generally, physics taught to non-physics majors. The project is national in its scope and involves physics academics from 22 Australian universities. This paper discusses the background to the study, possible drivers for change in teaching to non-physics majors, and proposes useful organisational models by which physics subjects may be categorised in which non-physics majors within Australian universities are enrolled. We also outline the directions of our future studies whose intentions include elaborating student expectations and experiences of physics subjects designed for non-physics majors.*

### Introduction

Physics and physicists have long had an image problem. Physics is perceived by many students as being a collection of complex facts, dull, and with little connection to today’s world. (Fonseca and Conboy 1999; Guisalsola, Almudi, Cerebriro and Zubimene 2002). Physicists remain stereotyped as middle-aged bearded men, wearing laboratory coats, surrounded by equipment and writing neatly in notebooks. (McDonnell 2005). Such an image does not add to the allure of physics for students, for example those drawn from the medical and biological sciences, who are required to enrol in a semester of physics in order to satisfy their course requirements.

Dissatisfaction with physics subjects delivered to non-physics majors has a long history (Lapp 1940) and though many approaches aimed at ameliorating the situation have been proposed, fervently held negative views affecting engagement with physics have withstood attempts of serious reformation. Perhaps this is not surprising, as studies such as those carried out by Sheila Tobias almost two decades ago, (Tobias 1990) have found that the absence of ‘community’, large class sizes and lack of contagious enthusiasm conspire to turn even extremely bright and intellectually ‘hungry’ students away from physics.

Though there is generally a shared understanding of the term ‘service teaching’ (at least within Australian universities), there are differences of opinion regarding which subjects should be classified as service subjects and which should not. For example, a service subject could be described as one delivered only to majors drawn from another School or Faculty (such as a Faculty of Engineering). Other descriptions would include physics subjects delivered to students within a Faculty (for example, physics taught to medical science students in a Faculty of Science). In this paper we have preferred to make the distinction between subjects routinely enrolling both physics majors (PMs) and non-physics majors (NPMs) and those enrolling only NPMs, as we argue that this distinction is functionally more useful and less likely to be a source of misunderstanding.

### Importance of teaching physics to NPMs

There are several reasons why the issue of provision of physics to NPMs, while far from being a new issue, deserves to remain a matter that attracts serious and sustained engagement by the physics community. Those reasons include:

- Those who were NPMs at university do a significant fraction of the teaching of physical principles in primary and secondary schools, both public and private, and will continue to do so for the foreseeable future. A recent study showed that one in four senior high school physics teachers in Australia had not studied physics beyond first year, and almost 43% of these teachers lacked a physics major (Harris, Jenz and Baldwin 2006). These NPMs are emissaries for the physics discipline in schools, with a key role of increasing the awareness of the contribution of physics to society. Their experiences of physics at university (which may be limited to a single semester of physics) will shape their attitudes towards physics and, by natural extension, those of the students that they teach.
- We have a precious (and in some cases a final) opportunity to promote physics to students who are destined to major in disciplines as diverse and sport science, civil engineering and forensic science. Equally importantly, there is a growing awareness of the importance of ‘physical thinking’, for example in the biological sciences, and that recent developments in this area are urging greater reliance on quantitative approaches to science of the type promoted by physical scientists. As Bialek and Botstein expressed it (Bialek and Botstein 2004):

*“...the fragmented teaching of science still leaves biology outside the quantitative and mathematical structure.....this strikes us as particularly inopportune at a time when opportunities for quantitative thinking about biological systems are exploding...”*

- At first year level, where by far the greatest number of students encounter physics, their initial experiences are crucial and influence the extent to which they are prepared to persist with their studies (Pitkethly and Prosser, 2001). Science in the US, for example, has been shown to lose 40% to 60% of students with higher than average abilities within two years of entering college or university. The retention rate worsens when minority groups are considered. As the educational experience and the culture of the discipline as communicated to students have a major influence on student retention (Seymour and Hewitt 1997), first year physics subjects which reach many thousands of students annually in Australia have a sizeable potential to affect, for the good or otherwise, retention rates in science (and engineering).
- The economic imperative cannot be ignored by Australian physics departments, as all teach a significant number of NPMs. A recent study (Pollard, Sharma, Mills, Swan and Mendez, 2006) reported that half of the physics departments in Australia rely on their service teaching income for more than 50% of their income. Service teaching has become increasingly critical as the amount of money available to physics departments to support teaching has declined over the past decade, affecting, for example, staff numbers. These have declined in Australia from in excess of 350 in 1994 to under 250 in 2002. Physics departments, for example those in the UK, who have ignored (or never had) service teaching to fall back on in lean times, have been downsized or closed altogether. To emphasise the seriousness of the situation; in 1994 there were 79 physics departments in the UK. By 2005 that figure had fallen to 48 (Parliamentary Office of Science and Technology 2007).
- The number of NPMs taught in every Australian physics department exceeds that of PMs. As an example, at a Sydney research based university around 1000 students enrol in first year physics subjects and of these only about 100 continue to major in physics. The NPMs are the ambassadors for physics, possibly continuing into careers with decision making capacity and capability to influence strategies and policies with potential impact on science in general.

## Drivers for change

There are contemporary drivers for change of the landscape of undergraduate teaching in universities that need to be accounted for in any review or revision of teaching to NPMs. For example, the adoption and development of models which are outcomes of *The Bologna Process* is fuelling the debate about generalist as opposed to specialist first degrees.

### *The Bologna Process*

In Europe, *The Bologna Process* is driving reforms to secure consistency and portability of qualifications (allowing, for example, credit transfer between higher degree institutions). It is recognised that this process will have a major influence on the development of higher education around the world (DEST 2007). *The Bologna Process* favours the creation of more general bachelor degrees followed by master degrees which are more specialised and ‘professional’ in orientation. If higher education policy makers in Australia are convinced by *The Bologna Process*, it is not difficult to imagine general science degrees in Australia increasing in number. These degrees may be expected to have physics as a core component, which in turn would lead to many more NPMs studying the subject, at least in the first year. In Australia, The University of Melbourne has already introduced major changes to its bachelor degrees which are now based on six broad undergraduate programs followed by a professional graduate degree (The University of Melbourne 2007). These changes may be seen to be congruent with some of the recommendations to come from *The Bologna Process* and may provoke other higher education providers in Australia to re-evaluate their offerings at bachelor level. It is timely to examine the extent to which serious ‘buy in’ to *The Bologna Process* and the models of provision of undergraduate courses that flow from the process, necessitate a rethink of the physics curriculum in general at undergraduate level, and especially in the first year.

### *The Research Quality Framework (RQF)*

The escalating focus on research carried out by Australian universities which is a consequence of the impending RQF has encouraged universities to redistribute scarce resources to maximise support for research. For some time to come this will have an unquantifiable effect on teaching and learning at universities. Possible outcomes of this are rationalisation of subjects resulting in increased class sizes, especially at first year level where teaching to NPMs dominates, reduced focus on curriculum and teaching developments and increased teaching workloads for those not counted in the RQF audit or designated as ‘research inactive’ staff. There is evidence that the Research Assessment Exercise (RAE) which has been carried out over the past 15 years in the UK has been responsible for an unwelcome distortion of values in the UK higher education system, leading to reduced emphasis on teaching and learning matters (Jenkins 1995; Banatvala, Bell and Symonds 2005). Another possible outcome is that once the pressure to carry out research is removed from the ‘research inactive’ staff, they become free to focus on enhancing teaching and learning. The establishment and success of the Higher Education Academy has provided professional development and a status for the ‘research inactive’ staff who have taken active interest in enhancing teaching and learning. A consideration of the models proposed here and their qualities can be used by decision makers to manage resources devoted to subjects designed for NPMs and make necessary changes. For the staff teaching particular subjects an analysis of the models will better help them understand the philosophy and learning and teaching practices within those subjects.

## Current models of teaching physics to NPMs

We describe the models of teaching physics to NPMs that we have identified in the Australian system. We recognise that in some situations a significant amount of physics is embedded within subjects in other disciplines (for example physics taught within civil engineering subjects within an Engineering Faculty). We have not attempted to broaden our study to include such subjects, though we remark that

a study of the costs and benefits of embedding significant amounts of physics within other subjects does deserve study.

We propose two models which allow for the useful categorisation of physics subjects taught to NPMs. We believe that the identification of subjects in universities across Australia that fit each model leads naturally to the consideration of benefits/limitations that may accrue from the adoption of each model. This in turn will form the foundation of a study of the impact of those models on student learning, experiences and attitudes towards physics. The information obtained about subjects which has allowed us to carry out the categorisation has mainly been obtained from publicly available, on line, university handbooks. In addition, we have obtained valuable and up to date information about subjects and courses from 11 universities which may be regarded as representative of a cross-section of Australian universities (including metropolitan, regional and rural based). A more thorough and comprehensive gathering of such data is planned.

### ***Model 1***

In model 1 subjects, PMs and NPMs are taught together and the subjects are prerequisites for later stage physics subjects. In some institutions students are enrolled in first year science courses without, at that stage, being classified as majors in any particular science and it is not until the end of the first year that it becomes clearer as to who are the PMs and NPMs. In such cases it may be better to describe students as intending PMs and NPMs. The syllabuses of model 1 subjects generally include topics that would be regarded as quite traditional, such as mechanics, thermal physics and electricity.

### ***Model 2***

In model 2 subjects, only NPMs are taught. It is convenient to have sub-classifications which reflect the extent to which the subject has been apparently designed for a specific audience.

Model 2a subjects are those, like Model 1, appear quite conventional first year physics subjects, but are predominantly ‘algebra’ based and so consist of NPMs only, as the subjects are not normally suitable as prerequisites for senior physics subjects. The syllabuses of these subjects are conventional in the sense that the topics and orientation of the subjects reflect a general introduction to physics with no obvious orientation towards other disciplines, such as engineering and the biosciences. These may reasonably be categorised as ‘service’ subjects as they do support the learning of students destined to major in areas other than physics.

Model 2b subjects again contain only NPMs and would not normally act as prerequisites for senior physics subjects but have an intentional, deliberate or overt orientation towards a particular clientele, be they majors in engineering, bioscience, agricultural or sports science. The available online data describing subject offerings is of sufficient inconsistency with respect to detail as to make reliable classification of Model 2A and 2B subjects difficult at this stage.

The number of universities that have subjects that align with the above models is shown in Table 1.

**Table 1.** Prevalence of models 1 and 2 in Australian universities

	Model 1	Model 2	Models 1 and 2
Number of universities	2	4	27

## **Considering the models**

In the first instance we intend to establish the robustness and usefulness of the models we have proposed to categorise subjects taught to NPMs. It is possible to consider approaches taken to physics teaching and learning, say at first year level, without categorising subjects by the apparent extent to which NPMs are ‘catered for’. We anticipate, however, that there will be several factors that will be

important to, say, student engagement with physics subjects by the way subjects are actually, or apparently, aligned to a student's degree and career intentions/aspirations. We hypothesise that a NPM student enrolled in a subject fitting models 1 and 2a, where there may be no attempt to align the subject with preferred graduate attributes/capabilities of the NPMs, may be less engaged than an NPM student enrolled in a subject conforming to model 2b. Staff from the 'serviced' disciplines are likely to also have views about physics service subjects categorised as conforming with models 2a and 2b which may differ depending on the extent to which the subjects conform with their expectations. We are also receptive to students' perceptions of the 'dumbing down' of physics, which may be associated with a subject designed for a specific audience. This perception may act to alienate students who suppose their physics subjects to be in some way 'inferior' to those designed for PMs.

We acknowledge that a subject may be titled, for example, 'physics for engineers' and though that subject could be classified as fitting model 2b, in actuality it may be extremely similar to a model 1 or 2a subject. Delving into the reality of the philosophy, teaching approach, syllabus content and related matters will be essential and require careful analysis of subject outlines, discussions with academics delivering the subject, and students to tease out, for example, what elements of a subject that evidently fits the model 2b description, relate directly to a student's major area of study. Despite this provision, we expect that several important facets of a subject, its organisation, teaching approach, resourcing, and the way it affects student engagement to show differences between subjects fitting each model.

More specifically, we would like to examine and map the relationships between subjects fitting each model to the issues described in Table 2.

**Table 2.** Matters to be considered in the context of subjects matching models 1 and 2

Concerning the:	Issues to be considered:
Student	Expectations, retention, self efficacy and self confidence, engagement
Subject	Design of laboratory experiences, assessment methods, teaching approaches, links with prior knowledge/experience
Curriculum	Alignment with graduate capabilities/attributes. frequency of update, extent of interdisciplinary representation of curriculum development committees, frequency of updates of curricula
Institution	Resourcing, local priorities/initiatives

Some of these relationships are likely to be difficult to tease out (for example, the effect, if any, of any particular model on student retention) as part of a one year study. By contrast, student engagement or attitudes towards physics, for example, are likely to be easier to establish. As part of the project we intend consider the issues described in Table 1, for example through the use of such instruments as surveys and focus groups, and to sample subjects aligning with models 1 and 2 which are representative of offerings of physics departments across a broad range of metropolitan, regional and rural universities in Australia.

The approach employed at the data gathering stage will consist of collating and reviewing subject outlines and teaching materials taught to PMs and NPMs across Australia to sufficient depth to allow for the classification of subjects as 1, 2A and 2B. It is our intention that the data be representative of universities across Australia, so that rural, regional, and metropolitan universities with diverse profiles (such as research based and practice-intensive universities) are included. This initial stage will be followed up by several in depth case studies to allow a broadening and deepening of the consideration of the nature and impact of physics subjects taught to NPMs. This will occur through student and staff questionnaires, interviews and focus groups sessions.

## Summary

In the first year of study, and even in research intensive universities in Australia, the numbers of NPMs taught by physics departments outnumber PMs by 10 to 1 or more. For some physics departments, there is only teaching to NPMs. As the next generation of physics teachers in schools will, in large measure, be drawn from the pool of NPMs, it is important that the physics community continue to challenge, and remediate where possible, negative stereotypical images that appear entrenched outside the physics community, as these images will continue to turn students away from physics. In an environment where drivers for change, such as the impending RQF, have the potential to significantly influence the teaching and learning landscape in Australian universities, it is timely to evaluate the current approaches we in physics have adopted to support the learning of students drawn from other disciplines. To assist in this process, we have proposed models by which subjects offered to non-physics major may be classified. The purpose of the classification is to clarify whether subjects that appear in harmony with specific models are particularly effective at encouraging student engagement, self-efficacy and impact positively on student retention. At a time when graduate attributes and capabilities are core to the mission statements of universities, we need to establish the extent to which subjects designed for NPMs are effective at fostering those attributes and whether, in pursuit of this goal, there is evidence that particular models are more successful than others.

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