Improving Student Engagement in 3rd Year Condensed Matter Physics: A Case Study.

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In 2004 the authors took over the third year solid state physics course at the ANU, which at that time had an enrolment of 10 students. Since then the course has been updated to include a range of interesting assessment tasks and a more open-ended laboratory course. In 2006, 41 students completed the course. The reasons for increased participation are discussed in this paper.

1. Introduction

In 2004, PHYS3032, Condensed Matter Physics (CMP) was a typical third year physics course at the ANU, with an enrolment of 10 students. In 2005 the enrolment doubled to 20 students, and in 2006 a total of 41 students completed the course, the highest of any third year physics course at the ANU. The course is the only solid-state-physics taught at the ANU, and the only exposure to the field for most physics students. Low popularity had meant that most physics undergraduates studied no condensed matter physics. The authors took over the course in 2004 determined to rectify this, not only because it is disappointing to teach an unpopular course, but more importantly because condensed matter physics is a key field of physics and a large fraction of physicists are engaged in solid state research and/or development. Many physics courses at the ANU do not include a lab component, so it is possible for a student to graduate with a physics degree having done no laboratory work since first year. Laboratory work is however a major component of this course.

The course curriculum was adjusted and modified from 2004 to 2006 following principles of good teaching and learning abstracted from education research (e.g. [1-3]), and using student feedback solicited from course evaluation surveys, focus groups, anonymous discussion boards and personal conversations. While this feedback has contributed to course development, only some of the suggestions have been implemented. Greater effort has subsequently been put into explanations for the students about the rationale for each assessment task and the modes of learning used in the course. The changes made are discussed below.

2. The evolution of PHYS3032

In 2004 the course consisted of 30 lectures, a few tutorials and a laboratory component of 15 to 18 hours lab work. The lectures covered the basics of solid state physics in a traditional fashion, beginning with an introduction to reciprocal space and diffraction techniques then moving on to crystal binding, phonons, electronic states in solids, Fermi surfaces and their significance, semiconductors and an introduction to superconductivity and magnetism. The textbook was Kittel [4]. The course finished with six lectures on ‘soft’ CMP and two on statistical mechanics. The assessment prior to 2004 was a traditional mix of laboratory reports, textbook problem set assignments and examination. 10 students enrolled in 2004, a typical number for this course at the time.

In 2004 we introduced two open-ended assignments: a short essay and a talk. These supplemented two problem set assignments, and unassessed tutorial problem sets. For the essay, students were given a range of topics but could also choose their own topic relevant to the course material. The short talk was to be about any application of semiconductors or superconductors. Essays were put on a website so students could read others' work. The essay and talk tasks were chosen firstly to encourage students to learn in more depth about one topic and engage in deeper learning [2]. Secondly, by choosing a topic of interest, a task can be more motivational than a set of text-book problems [3]. Thirdly, such tasks build generic skills, such as information literacy and communication (both written and oral presentation), addressed in few other assessment tasks throughout ANU physics courses. Tutorials throughout the semester provided problem sets. These were not assessed, but provided practice in examination problems, however students had to motivate themselves to attempt problems not completed in the tutorial.

With such a small number of students, course evaluation surveys have low statistical certainty, however the feedback was generally positive at the end of 2004. More importantly, the enrolment in 2005 doubled to 20 students.

In 2005 the laboratory component of the course was heavily revised, and the experiment workbooks rewritten to encourage students to think and question, and to extend the experiments where possible. Students could select which experiments they would do, subject to equipment availability. One new experiment in X-ray diffraction introduced students to 'real' research equipment and techniques. Students worked in pairs in the laboratory, and many experiments now had 3, 6 or 9 hour options, encouraging collaboration and self directed learning [3]. For assessment, students kept a laboratory logbook and wrote formal reports. Previously, many students had poor record-keeping skills, owing to limited laboratory experience.

In 2005 the syllabus of the course included a large component of statistical mechanics, replacing the 'soft' condensed matter. This part of the course was unpopular with students in 2005 partly because staff constraints required it to be taught out of sequence. As a result feedback and student evaluation were very mixed. Nonetheless, enrolments again increased in 2006.

In 2006, the course had more students than any other third year physics course, with the enrolment doubled to more than 40. The course content returned to the 2004 syllabus, but now with 9 'soft' CMP lectures. A new challenge was how to deal with the increased numbers, given limited laboratory resources and time. Additional experiments were added to the course, and two new experiments in electron microscopy were piloted. The students wrote a set of instructions for these experiments in place of an experiment report. One pair of students satisfied the requirements with a project in which they bought equipment, set up and tested an YBCO synthesis facility, and tested their own sample. They then wrote a report on their project and a description of the experiment for YBCO synthesis and characterisation. This was an extremely valuable experience for these students *and* added a new experiment to the course. Student writing of experiment instructions proved a far more valuable learning experience than was anticipated. The students reported that the exercise prompted them to think about not only the relevant experiment but also previous experiments. (The laboratory work for 2007 will consist of 18 hours chosen from: thermodynamics of Peltier devices, X-ray diffraction, magnetic susceptibility, energy gap in semiconductors, Hall effect, synthesis of YBCO, superconductivity of YBCO, magnetic hysteresis, diffraction and imaging using electron microscopes.)

The first assignment in the course in 2006 was made flexible by students choosing between an essay, a web page or 'other' activity in consultation with the lecturer. 'Others' proved extremely creative *and* enjoyable to mark, including a play about zombies that obey the nearly-free-electron model, a hands-on classroom exercise on digital logic with teacher's notes, a lattice/phonon simulator and a board game, Vortex! [5]. Students reported that they enjoyed these assignments, although some expressed concern that were not solving problems as examination preparation (problems were provided but not marked). The second assignment was a student-run symposium, for which students had to present a talk or a poster. Students who had presented fewer than three talks previously at ANU were required to speak. Again, this assignment was designed to be motivational and help development of generic skills as well as an in-depth knowledge of a topic in CMP. The afternoon-plus-evening symposium included a dinner with a speaker invited from ANSTO. It was completely student run, and peer assessed, and was an extremely enjoyable completion to the course showcasing the students' abilities as well as the aspects of condensed matter physics they found most interesting. The student ownership of the entire event both reduced workload for the lecturers and improved the atmosphere of the event – the course lecturers became guests of the students. Handing over some power and responsibility to students was a very successful way to end third year physics.

3. Conclusions and Implications for Course Design

Designing a course which gave students choice in some assessment tasks (e.g. assignment topics and experiments) increased student motivation for those tasks *and* for the course material overall. Collaborative learning improves motivation and helps students develop organisational and communication skills. The collaborative student-run symposium gave students a sense of ownership of this part of the course. These initiatives increase student motivation, improve generic skills and encourage deep learning.

Such tasks do not completely replace, but rather supplement and enhance, problem sets and exams. Nor do they require that something else goes from the syllabus. The syllabus for PHYS3032 was the same in 2006 as in 2004, and 2003, but it was a very different course in terms of student learning outcomes, and in enrolments. Some flow on is expected with more students opting to do research in CMP. Students from recent years' classes have gone on to take up a year-in-industry position with one of Australia's leading condensed matter research institutions and to present work and publish research at this Annual Condensed Matter and Materials meeting. Even those who do not continue in the field will still have an enhanced regard for CMP, something potentially important for any tasks they might perform on future committees and advisory groups, for government, industry, or academia.

References

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