[O5] Renovating laboratory teaching: keeping the students' interest

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Abstract

In recent years the Physics and Astronomy Department at the University of Glasgow has become aware of a growing dissatisfaction with the teaching of our laboratory classes, particularly at level one. Students found the work a 'chore', tackling the work as something that had to be done, rather than something they actually wanted to do. This attitude was having a detrimental affect on the students' views of Physics, and indeed on their performance. The Department concluded that this issue had to be addressed. This paper details the renovations carried out to the level one practical Physics class and reports on the improvements this brought about for the experience of the undergraduate students. The improvements focussed on the introduction of 'experimental tutorials' – a series of connected tutorials and experiments designed to clearly connect the theoretical and practical sides of Physics. The end result was a more intensive laboratory course which was well received by the students.

Introduction

For several years now, the teaching staff in the Physics and Astronomy Department at the University of Glasgow have been aware of a growing dissatisfaction with the level one Physics course. In particular, students appeared to dislike the practical classes. To address this apparent growing dissatisfaction it was decided to renovate the level one practical class. The course is split over two semesters, and it was decided to concentrate, initially, on reworking the first semester course. This paper reports on the renovations which were carried out and how well they succeeded.

Student preferences

Before renovation of the laboratory course could begin, a survey was carried out in November 2005 of the then current level one class, as well as students in higher years. The purpose of this survey was to determine what the students were looking for from the level one laboratory classes.

The students were first asked whether they felt the laboratories were a place to learn new, practical skills, or to help illustrate the coursework they were taught in their lectures. 65% of level one students, over 90% of level two students and 70% of level three students favoured the latter.

When asked about the structure of the experiments, 55% of level one students expressed a preference for having a clearly detailed list of tasks as opposed to using their own

initiative when approaching the work. The students from later years were more split on this topic – only 35% of level two students agreed to a preference for a clearly detailed list of tasks, whilst the level three students were split evenly between the two views. This is perhaps to be expected given that these older students have an obvious preference for the subject in the first place, having chosen to continue their Physics studies beyond level one. The level one students also did not want to be offered a choice of experiments to pick from – over 60% wanted the decisions made for them. Again the older students differed in their view regarding this (60% of level two students and 70% of level three students wanting the option to choose their own experiments). This result was not unreasonable – the majority of level one students do not have enough experience to pick their experiments.

The final two questions related to whether the students would rather work alone or in groups, and whether they would prefer more use of computer simulations. The clear majority at all levels was for pair or group working (over 90% in favour in every year group), whilst they did not want to see greater use of computer simulations. Instead they wanted to see more use of tutorials. Again, over 90% would prefer tutorials to simulations.

Aims of the renovations

Analysing the responses to the student survey allowed a new structure to be devised for the level one laboratory class.

Before the renovations took place, students attempted three five-hour experiments, accompanied by one hour tutorials every other week. This gave the students eighteen hours of laboratory time. Whilst the experiments which the students undertook had merit in terms of the Physics and practical skills they taught, they had not been updated in many years and were no longer seen as being in synch with the taught lecture courses. Since the students clearly indicated a preference for the experiments to highlight areas of the course covered in their lectures, it was felt that a wholesale recreation was needed for the laboratory course. This became one of the key aims of the renovations. The full aims were:

- to create direct illustration of lecture material – the laboratory course should be an integrated part of their lecture course, not separate to it.

- to encourage more free-thinking on the part of the students, within clear guidelines – tasks were phrased in ways which required students to use some initiative (e.g. a student might be told to plot a graph to confirm a theory, but not told explicitly what that graph should be).

- to bring in more research-style methodology. (e.g. greater emphasis on computer-handling of experimental data – previous experiments had used a lot of hand-drawn graphs).

- to create a faster paced working environment to avoid student boredom.

- to replace outmoded equipment.

Experimental tutorials

To insure that the students clearly saw the connection between the practical work and their lectures, it was decided to replace the traditional experiment structure with experimental

tutorials. These would consist of a theoretical Physics question, such as might be presented in a tutorial. This would be based on work recently covered in the Physics lecture course. The theory covered in the question(s) would then be directly mirrored in the experiment the students attempted. It was hoped that the students would be familiar with this approach, as it was in someway similar to that which they were familiar with from school where practical and theoretical Physics are taught hand in hand.

An example of one such experimental tutorial follows.

- *Course topic covered*: Hooke's law and simple harmonic motion (SHM)

- *Tutorial question*: the students were presented with the hypothetical situation of a mass oscillating on the end of a vertical spring under SHM. They were given the equation of motion for the mass and asked to sketch this motion. They were then given an equation for the force on the mass and asked to sketch how this varied. They were then given a final equation, detailing the period of oscillation, and asked to calculate a value for a given set of variables.

- *Experiment*: the students were presented with a practical duplicate of the hypothetical situation described in the tutorial question. The motion of the mass on its spring and the force exerted by it were monitored by sensors connected to a PC. The students carried out a series of measurements to monitor motion and force, and then calculate the period of the oscillations. If the students carried out the experiment correctly, then the computer would produce graphs similar to the ones they had sketched from the theory. They would then use the same data to calculate the period of oscillation and compare this to the value from theory.

By carrying out this experimental tutorial, the students came at the idea of Hooke's law and SHM from both a theoretical and a practical direction.

This particular experiment also met one of the other aims of the renovations – specifically the updating of experimental equipment. An earlier incarnation of this experiment had had the students manually counting and timing bounces of an oscillating mass. The use of a computer to do these calculations considerably improved this experiment. The experiment also required the students to carry out data analysis and manipulation within the Microsoft Excel package, meeting another of the broad renovation aims.

Before the students began the series of experimental tutorials, they carried out an intensive IT exercise. A large proportion of this was designed to introduce the students to the many uses Microsoft Word and Excel have for the modern physicist. The exercise saw the students creating scientific diagrams, tabulating data and then manipulating that data in Excel. These Excel skills were further developed as the term progressed. A subset of the experimental tutorials, including the one detailed above, had an element of data analysis as a key component.

To match up the experimental tutorials with as many of the topics in the lecture courses as possible it was decided to shorten each individual experiment to one hour in length, with each student attempting three such experiments in every three-hour laboratory session. To accommodate the number of students, each group of students was divided into three, with each group progressing through the three experimental tutorials as the laboratory session went on. The level one lecture course is divided into three separate topics, so wherever possible each laboratory session had one experiment from each topic.

This structure was adopted for the first five weeks of the laboratories, making a total of fifteen new experiments. The final three-hour session was different. Here, two ninety minutes exercises were designed to promote team-working skills. One of these was a theoretical exercise, testing the students' knowledge of special relativity. The second was a practical exercise where the teams (of typically four or five students) were given a set of tracks and supports and asked to design a roller coaster which would illustrate certain aspects of dynamics; which aspects were chosen was left up to the students. In both of these exercises, assessment was based on a short presentation given by the group at the end of the ninety minutes.

To create the seventeen new experiments, the lecturers from the level one course were asked to select a series of topics from their course components and devise the basics of an experiment which would illustrate each of these topics. An Honours level undergraduate student in the Department was then employed over the summer of 2006 to work through these basic plans and flesh them out with the help of the members of staff. The end result was a diverse collection of relatively straightforward experiments which covered a wide range of topics covered in the lecture course components.

Results

These new experiments were first deployed between October and December 2006. After the first week it was decided that it was not practical to have the students attempt three experiments in each three hour session. The time allocated to each experiment was instead increased to ninety minutes and each student expected to attempt two out of the three available each week. The students were assigned to the experiments each week, as the information we had received from the original questionnaires suggested that they did not wish to have to make the choice themselves.

Whilst this reduction in experiments attempted meant that the students covered less material than had originally been planned, the extra time allocated to each experiment meant that the standard of the work carried out improved. It also made the job of the demonstrators considerably easier. They could now actually provide useful guidance to students, something which was felt to be essential to the students' laboratory experience.

To assess how well these new experimental tutorials were received, a new questionnaire was given out at the end of the semester. Even before this was given out, however, it was apparent that the level of activity in the laboratories had improved. When previous cohorts had attempted the older, longer experiments, there were often periods where the students were clearly losing interest in the work. Under the new structure their attentions remained focussed on the work at hand. This was perhaps in part due to the more hands-on approach of demonstrators who were also 'refreshed' by the new work.

In the survey the students were asked to rate the standard of the level one laboratory class as 'Excellent, Good, Fair, Poor or Very Poor'. 60% ranked the laboratories as good or excellent, with another 37% ranking them as fair. The students were also asked to rank the standard of the demonstrators on the same scale. Here 77% of the students considered the demonstrators excellent or good, 17% as fair.

This feedback was, in itself, very encouraging. Whilst they were not the same cohort as those polled in the first questionnaire – clearly not possible as those former students did not undertake the new structure – they clearly felt that the experimental tutorials were a useful exercise.

The students were also asked to compare their experiences in the Physics level one laboratory with other laboratory courses they were taking, if appropriate. Specifically, they were asked how the Physics labs compared to those of the Astronomy and Chemistry courses.

The results were mixed. In comparison to Astronomy, the students' views on the Physics laboratory were encouraging. There was a three-way split of opinion in regard to the Astronomy laboratories. One third of the students thought the Physics laboratories were better, one third thought they were worse and one third thought they were just the same as the Astronomy laboratories. This may not, at first glance, seem like an encouraging result. However in previous years, the Physics laboratories had always been considered much poorer than their Astronomy counterparts. The fact that opinion is more divided, therefore, suggests that progress is being made.

When compared to Chemistry, though, Physics did not fare so well. Over three quarters of students taking both courses felt that the Chemistry laboratories were better than the Physics ones. When asked to give more details on why the Chemistry laboratories were viewed more highly, the responses fell broadly into two categories. Either students felt that the Chemistry laboratories were less rushed/better organised, or they felt that they were easier. The former problem is not too surprising since this was the first year which the new Physics laboratory structure was being used, and this inevitably meant occasional mistakes cropped up. The latter problem is what might be called a 'classic' – students will often prefer courses which appear, to them at least, to be easier.

Conclusions and future work

Discussions with undergraduate students in the Physics and Astronomy Department had highlighted a growing dissatisfaction with the practical side of the teaching of the course. Students felt it was disconnected from the taught work and of little purpose. A subsequent survey of level one students past and present provided guidance on what the students were looking for. This enabled a renovation of the practical class to better meet the expectations of the students, whilst retaining the educational merit desired by those teaching the course. Lengthy experiments were removed and more focussed experimental tutorials brought in. These directly linked the taught course work with the laboratory class, drawing out key aspects of the course to further strengthen the students' learning.

Student reaction to these changes has been broadly favourable and the initial aims of the renovations have been met:

- *to create direct illustration of lecture material* – each experimental tutorial specifically tied into an aspect(s) of preceding lectures.

- *to encourage more free-thinking on the parts of the students* – students had to work out what to do with data, which equations to use and so on.

- *to bring in more research-style methodology* – many of the experiments used modern data acquisition computer packages to analyse results efficiently.

- *to create a faster paced working environment* – students undertook two experiments per three-hour session instead of one over five hours. This reduced time forced students to concentrate on the tasks set them and kept them working.

- *to replace outmoded equipment* – a wide range of new equipment was purchased, including PC-based data acquisition systems and digital oscilloscopes.

The introduction of these experimental tutorials was always intended as just the first stage of an on-going improvement in the practical teaching. As well as further adapting these tutorials in light of the experiences running them, more renovations will be needed to insure that the students' experience continues to improve as they progress into the second semester of level one and then into higher years of the degree course. Already the semester two level one labs have been altered to somewhat match the experimental tutorial structure. In place of three, five-hour experiments, students attempt six, three-hour experimental tutorials. These experiments will focus more on developing laboratory skills than on following up lecture material as these are important skills for the students to develop. There will also be a greater emphasis on error analysis and on writing scientific reports. The aim is that by the end of the full year the students will have well-rounded, high quality skills in a wide range of practical Physics.

The overall intention of these renovations was to improve the level one practical Physics teaching. This improvement had to not only be from an academic's point of view, but also apparent to the students. The information presented here shows that this overall intention was successfully achieved. What is particularly encouraging is that the students' views of the laboratory are positive despite the fact that more is now expected of them. There is often a view that 'better = less work'; the results here suggest that if the correct changes are made, this is not necessarily the case.