PROF532-10C The Professional Practice of Tertiary Teaching

Task One: Design, implement and evaluate a class or assessment task that draws on workshop learning.
The use of learning outcomes for papers is now widespread across the tertiary sector, including at the University of Waikato. A learning outcome is an indication of how a teacher or a student would recognize that a student has learned what is required (Biggs & Tang, 2007, p. 7). Outcomes should guide assessment methods, and assessments in turn should guide teaching. The assessment is therefore central to the learning process, and as such a well-composed assessment should guide successful students to meeting the learning outcomes.

Attendance at Teaching Development Unit (TDU) workshops and seminars has highlighted to me the motivating power of assessment for students. It is “at the heart of the student experience” (Brown & Knight, 1994). Whether it is simply to get a good grade (achievement motivation) or to demonstrate their learning to themselves (intrinsic motivation), most students will pay close attention to assessments (Biggs & Tang, 2007). For this reason, they are an essential part of the learning process.

In this task, I considered assessments within the paper PHYS204, Experimental Physics. I have taught this paper since 2005. Typically, the class consists of around 12 students, about half of which are undertaking physics majors within the BSc degree, with the other half taking a Bachelor of Engineering degree or chemistry major within the BSc. As is common in physics, the typical student is male and introverted, although some have excellent practical skills. International students are usually a small minority for this paper, possibly because it is more practically-rather than theoretically-focused. In 2010, this paper contained nine students (eight male, one female), all New Zealand educated.

The main purpose of the paper is to teach students how to perform a good physics experiment. Specifically, the first learning outcome is: “the students who successfully complete this paper will be able to plan, carry out, and document experiments”. Since I have taught the paper, I have had doubts as to what extent students have been able to plan experiments. My observations in the laboratory sessions suggested that students typically put very little effort into preparing before a laboratory session. In the third year experiments of PHYS301 (Biophysics), where instructions are much less defined, students who have been through PHYS204 often are unable to put together a sound methodology. By ‘planning’, I use the definition of Gibbings et al. (1986): (i) defining the objective of an experiment, (ii) bringing together existing relevant information, (iii) identifying constraints on the work e.g. due to resources, and (iv) producing a procedure to be used.
In 2008 I introduced a lecture dedicated to experimental planning, but this was extremely difficult to give as it is a subject that probably can best be experienced practically. In 2009, following suggestions arising in a TDU workshop, I introduced an assignment in which the students looked back at an experiment they took in their first year physics paper, and modified it to be suitable for second year. I felt this was a better approach than a lecture, but the assignments were not well done, possibly because the students did not fully understand the instructions.

This year, I have chosen to teach experimental planning in a practical, rather than theoretical way, and it is this that forms my assessment initiative. The bulk of the assessment of the PHYS204 paper relates to the weekly experiments that the students undertake. For these experiments, instructions are provided, albeit in less detail than for first year, meaning that the task of ‘planning’ the experiment is for the most part removed from the student. Each week, their work is marked (i.e. each experiment is an assessment task in its self). Each experiment contributes 5% to the overall grade for PHYS204. This year I have made changes to a number of these laboratory sessions, which should lead to students being better able to ‘plan’ an experiment, as stated in the learning outcomes.

The problems with the traditional ‘cookbook’ approach to teaching experimental work in physics, in which detailed instructions are given by the teacher, have long been known. For example, Prescott & Anger (1970) documented an approach in which first-year students were asked to design their own experiments. They found that students’ thinking shifted from following procedures towards developing an understanding of the underlying physics. However, this approach came at the cost of increased planning by the lecturers and graduate assistants.

More recently, Lippmann (2002) found that students (both strong and weak) who are required to design their own experimental methods undertake more ‘sense-making’ conversations with each other and teachers than those given detailed instructions. This conversation frequently produces learning in the sciences. The latter group spent a large majority of their time on logistics – carrying out the instructions. For the stronger students in the latter group, ‘sense-making’ could be activated by asking them questions in which they had to explain what they were seeing. However, this strategy did not work for the weaker students.

Karelina and Etkina (2007) have made a detailed comparison of conversations within groups of students undertaking student-designed experiments and ‘cookbook’ experiments. Crucially, students who undertook design-based courses spent more time thinking and
talking about the experiments than actually doing them. Their discussions were found to be at a deeper level (more scientist-like). The ‘cookbook’ students answered reflective questions very superficially, suggestive of surface learning. Interestingly, despite having detailed instructions, these students asked for more help than those required to design their own methodologies.

The activity of design-based science experiments is probably well-aligned to Kolb’s learning cycle (Kolb, 1984). Here a learner will reflect on a previous experience (e.g. an experiment), and try to conceptualize these experiences, which will suggest a path forward. At the next opportunity, (the next lab session) their new conceptual ideas would guide them (e.g. they would approach the next experiment slightly differently). This in turn would result in new learning experiences on which to reflect. Students carrying out design experiments become both ‘reflectors’ and ‘sense-makers’ (Lippmann, 2002), allowing them to fit in well with this cycle. With sufficient time students are likely to improve their experimental abilities (Etkina & Murthy, 2006).

The assessment task

For this assessment task, I have chosen to intersperse the ‘cookbook’ laboratories of the PHYS204 paper with three ‘design’ (or ‘planning’) laboratory sessions. For the design sessions, the instructions provided are very brief. It is left up to the student to design his or her own methodology. Ideally, I would include more design-based sessions; however, there are practical limitations. One of these is the need to review the experiment with student design in mind, which takes considerable time. A second relates to the equipment. It is essential that students are familiar with the experimental equipment before they can design their own method, otherwise they become distracted by operating the equipment as opposed to thinking about the experiment (Etkina & Murthy, 2006). The current first-year physics paper, PHYS103, does not adequately introduce students to the range of equipment used in the second year. Therefore I have chosen to ‘pair’ laboratory sessions. In the first of a pair, students carry out a ‘cookbook’ style experiment that introduces them to the equipment; in the second, they carry out a ‘design’-based experiment. Finally, because we possess only one set of equipment for each lab session, we operate a roster system and this severely restricts flexibility.

I felt that modelling this task was important, since it was new to the students. Therefore, in the first laboratory session of the year, we undertook an experiment as a group. This was not assessed. I guided the group through the experiment, including planning how to use the
equipment, working out what range of readings to take, and processing the results. My intention was to give some confidence to the students that they understood what was required.

Link with learning outcomes

The learning outcomes for this paper are shown below.

Students who successfully complete this paper will be able to:

1. Plan, carry out, and document experiments
2. Use common physical instrumentation
3. Process and analyze data in a meaningful way
4. Account for and minimize experimental uncertainty
5. Discuss the significance of their results
6. Produce a basic scientific report.

Assessment tasks for this paper consist of 11 weekly experiments (accounting for 55% of the final grade), three written assignments (25%), and two formal reports (20%) in which two experiments are written-up in the style of a journal article. The experiments address the learning outcomes 1 – 5; Outcomes 5 and 6 are addressed through the two formal reports. The first assignment is a written exercise involving experimental uncertainties (outcome 4); the second a task involving data-processing and plotting appropriate graphs (outcome 3); in the third, the students use units and dimensions to interpret physical processes (outcome 3).

The first two outcomes are assessed only through the weekly experiments. Outcome 2 is usually quickly met by most students simply through the practical use of new equipment such as oscilloscopes, micrometers, optical adjusters, Geiger counters etc. in the laboratory sessions. However, outcome 1 has been more difficult for students to achieve. Carrying out an experiment and documenting it is not usually a problem since instructions are provided; but, planning the experiment is not something that students are able to do well. Partly, this is because they have been given only limited opportunity to do so (since instructions are provided), but, perhaps more significantly, the course is structured such that they can pass (with a reasonable grade) without having thought about an experiment before they start the laboratory session.

This task is aimed specifically at guiding students to meet this learning outcome, particularly at a student’s ability to plan an experiment.
Evaluation strategy

To determine the success of the assessments, I have drawn on three sources. First, I have used appraisal questionnaires. I have included the question “The ‘planning’ experiments assisted my learning”, which has been answered on a Likert Scale. Additionally, students have provided free written comments on the appraisal forms.

Secondly, I draw from focus groups. Before the start of this paper, I used a focus group to look at the learning of the 2009 student cohort with regard to experimental planning. At the end of the paper, a similar focus group was held to look at the 2010 student cohort.

Finally, I have written down extracts from conversations that have been carried out during the laboratory sessions themselves. These provide clues as to how students are thinking. The sessions were not recorded; conversations that I thought were relevant were written down by me as soon as practical afterwards. Although the exact words recorded may not be correct, I believe the themes they express are valid.

These approaches all draw heavily from the students’ own views of their own learning. This has to be viewed with some caution; for example Kortemeyer (2007), drawing from the Maryland Physics Expectations Survey (Redish et al., 1998) describes how a student’s reporting of his views on learning does not correlate well with how he actually learns. However, Kortemeyer also reports that a study of student conversations (the third strand of my evaluation strategy) was found to be a reasonable predictor of student learning.

Results

Conversations

In general, the implementation of these assessment tasks went well. Nearly all students engaged very well – despite their initial apprehension they appeared to enjoy the tasks given to them. One student in particular relished the opportunity to work out a methodology for himself:

“[The planning experiments] give you freedom; you have to think about it and decide what’s important. You learn more by doing them.”
Another student was forced to spend time thinking about the experiments when he would usually turn up to the laboratory having done no preparation. He appeared to be ‘strategically oriented’ (Biggs & Tang, 2007); he had learned that he could get reasonable marks in many experiments with little effort simply by following the instructions, and was employing that strategy successfully to minimize his workload. When I challenged him on this, he justified his approach on the grounds of time: “Do you know how many assignments I have?” At his first ‘planning’ experiment, he was underprepared (though still better prepared than for non-planning experiments), exemplified by the question “What range of paper thicknesses do I need?” Removing instructions from him removed the option of employing the strategy of follow-the-instructions and this individual’s marks showed substantial improvement. While I think it would be unfair to call this student a ‘surface’ learner, he was forced to shift his strategy towards ‘deeper’ learning (Biggs & Tang, 2007)

However, not all students found these experiments helpful. One student struggled on all three experiments where he had to plan the methodology himself. He appeared not to understand what he was required to do.

“Well, I didn’t know what I was doing, really. These [planning] experiments are hard”.

It is noteworthy that this student would be the one who would read the laboratory instructions for the ‘cookbook’ laboratories in most detail – often to the point of not touching the equipment until halfway through the session.

**Student Questionnaires**

Overall, the Likert questions gave similar scores to 2008 and 2009. A score of 1.1 was given for overall satisfaction with the quality of the paper (compared with 1.2 and 1.5 in 2008 and 2009 respectively) and a score of 1.3 for overall teacher effectiveness (compared with 1.0 and 1.5 in 2008 and 2009 respectively). Since I am the sole teacher, paper effectiveness scores and teacher effectiveness scores are probably closely related.

In answer to the specific question “I found the planning experiments useful”, four (out of eight) students indicated ‘always’, two indicated ‘usually’ and two indicated ‘seldom’.

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1. This individual’s average mark for the planning experiments was 84%, compared to 74% for the non-planning experiments.
2. In the appraisals, ‘Always’ is awarded a score of 1; ‘Usually’, 2; ‘Sometimes’, 3; ‘Seldom’, 4; and ‘Never’, 5.
Student opinion appears split. In hindsight this is not surprising; such a style of learning is new to them.

Unfortunately, at the time of writing (November 2010), the free comments on the appraisal forms are not available to me.

**Focus Groups**

Before embarking on the assessment initiative for PROF532-C, I undertook a focus group study of the 2009 student cohort to ascertain their experience of experimental planning. Three students contributed from a possible five. Attendance was voluntary. The students were found to have developed a strong appreciation of the need to plan an experiment, and the time taken, but not the ability to do it themselves (*i.e.* learning objective 1 had not been met). One student commented that “[planning helps] you to make sense of the results…[and] gives you feedback on what you have done.” This shows a strong understanding of the importance of planning. However, the further comment “He must plan it really well for it to take us three hours” suggests that the student recognized that it was the teacher, not himself, that had undertaken the bulk of the work.

A focus group was also held for the 2010 cohort of students. Unfortunately, only three students took part from a possible nine. Again, attendance was voluntary. One student took part orally (Student A), and two took part via email submissions (Students B and C). Given the spread of opinion about the planning experiments indicated on the appraisal questionnaires, it was disappointing that there was no element of discussion at the focus group.

Identification of themes from a small sample is difficult. However, all students commented that the planning experiments led to them thinking more about what was going on (*i.e.* engaging with the subject more deeply):

“*It made you think about what you were doing*. (Student A).

“*[The] method of giving us labs to design ourselves can be challenging, but in a good way and most definitely helps us to learn more about what we are actually doing and why.*” (Student B).

“*From here, I can take all the experience I learnt in that experiment and use it to plan a refined experiment...*” (Student C).
There were several remarks made that addressed experimental planning directly. One student said that the ability to “plan and run experiments” were the main skills he had learned. He expanded on this:

“So, for a planning experiment ... it made you think about what you were doing and being familiar with the whole nature of physics.” (Student A).

This comment shows that the student had engaged with the planning process and had started thinking more deeply about the physics involved. This is consistent with the findings of Karelina and Etkina (2007).

Students also commented on the paired approach towards experiments:

“The first go with the apparatus, I wasn’t familiar with it at all. So I took a lot of time to come to grips with it and use it, and ...[I] didn’t get much time to think about what [I was] doing, [I was] just following the book. And the next time round, [I] could prepare...” (Student A)

“There was sometimes the expectation that a student can take up a piece of apparatus, and use it at its optimum efficiency, without any prior familiarity.” (Student C).

Here, the second quotation is in reference to a ‘cookbook’ experiment in which the student encountered the apparatus for the first time. These comments suggest I was wise in paying attention to the literature and ‘pairing’ experiments.

**Reflection and Review**

I have been encouraged by the way these assessment tasks have been tackled by the students. Working closely with them in the laboratory sessions has enabled me to experience feedback first-hand from students; this has been valuable. The conversations I have had have been enlightening. Overall, I believe that the students have learned from and mostly enjoyed the planning experiments. The feedback from the two focus groups suggests that the 2010 students as a whole developed the ability to plan experiments (i.e. met the learning outcome) whereas the 2009 students did not; therefore I consider this series of assessments successful. Brown *et al.* (1997) have commented “Changing the mode of assessment changes the mode of student learning” (p. 250); my experience in this
paper bears this out. However, I was disappointed by the lack of student co-operation with the focus group – this has meant that feedback to me has been less comprehensive than I would have wanted. I intend to continue with the planning experiments in future years, but monitor their success closely.

Interestingly, as a whole, there was no difference between the marks awarded for the planning-experiments and the conventional ‘cookbook’ experiments. Overall, students undertook the planning experiments did just as well as they did with the ‘cookbook’ experiments; the quality and validity of their results were equivalent. However, the focus group and questionnaire evidence shows that through this new approach, some students (but maybe not all) learned more about planning (i.e. met the learning outcome 1) and engaged more deeply with the subject (Karelina & Etkina, 2007).

I found that undertaking experiments in pairs – first introducing the students to new equipment, then have them perform a planning experiment with it – meant that the equipment did not become the focus of the experiment. This is in line with the suggestion of Etkina & Murthy (2006). Without this pairing the result of this exercise may have been less positive. However, this set-up introduced timetabling restrictions. Equipment (most of which is not duplicated) had to be used by the same pair of students two weeks in succession. I was only able to put in place three planning experiments throughout the semester. Ideally, I would make this much larger (at least five). More equipment would relieve this situation. For 2011, I shall look more closely at the timetabling options and try to develop a greater number of ‘paired’ experiments.

This paper is just one component towards a BSc degree, and as such needs to be considered in a broad context of developing a student’s skills. This work suggests that looking at the way experiments are undertaken in first year, in the PHYS103 paper, might be worthwhile. The University of Waikato graduate profile for the BSc indicates that students will have had practical laboratory experiences that prepare them for the workplace (University of Waikato, 2010). In order to move students towards this outcome, third-year experiments in PHYS301 are much more open-ended than for PHYS204 and PHYS103; however, there is potential for them to be made more so. Students having done PHYS204 this year might now expect that to happen.

I am looking forward to presenting this work at the upcoming Australian Institute of Physics congress in Melbourne in December 2010, and hope to receive some useful feedback from my peers on ways forward.
References


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