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PROF532-10C The Professional Practice of Tertiary Teaching

Task Two: Design and Evaluate a Teaching Initiative

Background, current practice and rationale for the initiative

In physics, it is critical that a student grasps concepts correctly, since one concept is often built upon a previous one. There are numerous ‘threshold concepts’ (Meyer & Land, 2003) that need to be taught carefully, and a student’s failure or ability to understand needs to be identified. Students’ prior learning is important; incorrect concepts that they are bringing into a course, or developing throughout the course, need to be identified before they can be corrected. For example, Halloun and Hestenes (1985) have shown that initial knowledge and conceptions about motion have a large impact on performance in mechanics classes. However, traditionally based physics courses, along the lines of my current teaching practice, do not necessarily give opportunity for a teacher to identify such misconceptions. For example Mazur (1997) has demonstrated that students can perform well in traditional physics assignments while having incomplete or incorrect knowledge of the underlying concepts. However, where students are actively engaged in lectures, as opposed to purely listening to a lecturer, understanding improves (Hake 1997).

My current focus in teaching has been typically towards teaching content, rather than ensuring conceptual understanding. Although I am beginning to see the benefit in focusing on concepts and skills, I still feel somewhat constrained by the need to give students necessary content so that they are prepared for future papers. This experience is common among physics lecturers; Turpen and Finkelstein (2009) report that physics teachers’ decisions on their practice are strongly guided by the constraints they perceive to be present; the need to teach content is one of these (Henderson & Dancy, 2007).

The papers that form the focus for this work are the second year paper ENEL285, Quantum and Solid State Physics, containing around 20 – 30 students a year, and the third year paper ENEL312, Electromagnetic Waves, typically with about 15 students. Both papers have students enrolled either in the Bachelor of Science degree (with physics as a major subject) or a Bachelor of Engineering degree (with an electronic engineering specified programme). They contain many more introverts than extroverts; this fact is important for the manner in which I teach. Approximately twenty per cent are international students. I have been teaching half of both papers, for the last four years.

In order to ensure that I give due focus towards students’ conceptual understanding, I need to have methods in place to gauge a student’s grasp of the underlying concepts. Dufresne and Gerace (2004) have discussed a strategy for formative assessment in lecture classes, with a view to aiding both the teacher and the student. This involves asking students multiple choice questions in class, which then leads to a class discussion. Mazur's strategy is more specific (1997); he recommends that students first answer questions individually, then discuss in pair and small groups, before revealing their choice to the teacher. Indeed, he recommends building the entire class around peer discussion of questions. Discussing realistic problems in small groups is part of what would be experienced in a science or engineering workplace. Indeed, the Graduate Profile for a Bachelor of Science degree at The University of Waikato (University of Waikato, 2010) states that a graduate should have "a capacity to think innovatively and to solve problems".

The innovation

For this assignment, I have chosen to try out part of Mazur's strategy. Specifically, at the start of each lecture, I presented two multiple choice questions that related to the concepts discussed in the previous lecture. The students were given a minute to think about their answer on their own, and then two minutes to discuss them in pairs or small groups. In this discussion time I listened to what was being said. The students then voted, by holding up cards. Ideally, I would have used a Personal Response System (clickers) but these are not currently available to me. I then revealed the correct answer. If there were clear difficulties among the students' thinking, arising from their answers or from their discussion, I enquired further to try to understand what they were, and then attempted to correct them, often drawing on further student discussion.

The teaching initiative described here was intended primarily to give me feedback on how students are performing, and grasping concepts, outside of the written assessments done by the class. It was designed as a formative, not summative, assessment task. Secondary intentions were to get a class of usually very quiet students to discuss issues, and to give students themselves feedback on how they are achieving.

With this innovation, there were several issues that needed consideration. First, as identified by Ding *et al.* (2008) in a physics context, assessment conditions affect students' participation and performance. For example, when credit is given for taking part, participation rates increase, and when credit is given for 'correct' answers, performance increases. I gave no formal credit for participation in this task, but monitored throughout the semester how many students actively were involved in the task.

Second, students' participation may be influenced negatively by the need to reveal to their peers and the teacher what their thinking is. This may be a larger factor in physics and engineering than in other subject areas, given the shyness of the individuals. Indeed, for the

ENEL285 tutorials in 2008 I attempted to encourage discussion by asking students to explain their answers to questions to each other. At the time I felt this was disastrous – the students did not feel that this approach was for them and would respond by sitting in silence for several minutes. Indeed, one student approached me after one such tutorial and reprimanded me because, in his opinion, I was neglecting my role as a teacher. Turpen and Finkelstein (2009) have shown that the ability of students to "[identify] themselves as sources of solutions" in this way depends on how the teacher implements the strategy in practice.

Third, the effect of timing of the formative assessment matters (Sayre & Heckler, 2009). When tested immediately following the concept (*e.g.* the following lecture), results are typically more favourable than if tested several weeks later.

Fourth, the nature of the questions need careful thought. It is important that questions are able to lead students into making sense of physics, not simply solving problems. For example, Gire *et al.* (2009) have shown that the way students thought about physics did not become more expert-like across the first three years of a four-year degree; many students hold to the incorrect assertion that physics is about solving traditional textbook-style problems. This view is unsurprising given the unhelpful style of question popular in many lectures and books.

Fifth, formative assessment tools of this form are recognized as being an ideal pillar on which students can build their learning. For example, Dufresne and Gerace (2004) and Mazur (1997) take this strategy for physics, and Keeley *et al.* (2007) recommends it for science in general. My use of this formative assessment could be taken beyond merely providing feedback, by exploiting the opportunity it gives for student learning.

Finally, by spending sometimes as much as half the session looking at the multiple choice questions, time to cover content is much reduced. This requires student co-operation; they are required to read material outside class that would previously have been discussed in class. Unlike previous years, the summative assessments covered material that I did not cover in class. This is unusual for physics courses.

A broader issue, not specific to this innovation task, was the difference between the needs and expectations of the students studying for an engineering degree and those studying for a physics degree. The two groups have been shown to think differently about physics (Gire *et al.*, 2009).

These issues will be pertinent when I analyze and reflect on the success of this initiative. I did not offer any incentive for participation or giving ‘correct’ answers; this was enforced on me because the course outline with summative assessment criteria was already in existence. The extent to which students co-operate is an aspect I monitored as the semester has progressed. Although it was fascinating, I chose not to carry out the full peer-learning approach suggested by Mazur (1997) for two reasons; first that it involves a considerable amount of effort on the part of the teacher to re-write an entire course, and secondly that it may be too large a jump for many students in terms of the teaching styles with which they are familiar. By allowing discussion to build from the questions, particularly when I perceived the students were using it to learn, the time available for presenting content was necessarily reduced. Students were left to cover some material in their own time.

Evaluation

Evaluation of this strategy is not straightforward. For some physics topics, *e.g.* mechanics (Hestenes *et al.*, 1992) and elementary electromagnetism (Maloney *et al.*, 2001) there are well-validated sets of questions by which assessment of students’ conceptual learning can be made. For more specialized topics, such as the ones I teach here, such question sets are lacking.

There are several threads to the evaluation process. The primary method is through the student appraisal system. Specifically, I have added to the questionnaire a Likert-scale statement ‘I found the questions at the beginning of the lectures helpful’. This will bring some quantitative data to the analysis. Associated with this, the students’ free comments provide feedback on how they found the strategy.

A second thread to evaluation is the internal summative assessments and exam results. If formative assessment is implemented well, it should allow teachers to “adapt teaching and learning to meet student needs” (Dufresne & Gerace, 2004), thereby improving performance in summative assessment. However, comparison of summative assessments between this year and previous years is problematic because classes are fairly small, and there is significant fluctuation in class exam and assignment results from year to year.

A third, but less rigorous evaluation can be made on the basis of the time taken in class discussing the multiple-choice questions. If a significant portion of time in a particular lecture is taken up in this way, one can infer that students are needing this extra opportunity to grasp the concept, *i.e.* that I have successfully identified that the student group has not understood, and therefore that this teaching innovation is working.

Review of process and evaluation data

The teaching strategy was implemented first of all in the third year Electromagnetic Waves class (ENEL312-10A), in the first half of the teaching semester. This was followed by implementation in the second year Quantum and Solid State Physics class (ENEL285-10A) after the mid-semester break. In the first lecture of both classes, I described what the students should expect, and explained why. My intention was to ensure that all students could see the purpose in this approach to teaching, which was probably new to most of them. Mazur (1997) reports that participation is greater when students appreciate why a strategy is being used.

I was worried that by starting each class with these questions many students would choose to come late to class. Ding *et al.* (2008) has found that when students are not given incentives to participate, rates of participation in first-year Electricity and Magnetism assessments were lower. Also, I felt that many students might not wish to take part in any discussion, nor display their choices of answer openly. Overall, this was not the case; student engagement with this strategy has been excellent. The third year class, in particular, had nearly 100% buy-in from the students; that is, no students missed the first part of the lecture, and nearly all students engaged with the questions asked. In the second year class engagement has been a little lower; some students have not taken part in discussion despite me personally explaining to them that it might be beneficial to their learning. This group grew to about 25% of the class by the end of semester. However, these students have still attended class, and appeared to listen to what is being said. One talked to me personally about the questions during study week as part of his revision. The reasons for a student's choice not to co-operate with the strategy may be worthy of further investigation.

During the second half of the semester I was away from Hamilton unexpectedly for two weeks. The lectures were taken by a colleague who also used the multiple choice questions at the start of each lecture. I do not believe my absence has had a major impact on this strategy.

Course Appraisals

All the students who completed the appraisal questionnaires for ENEL285 indicated that they 'always' found the questions at the start of the lecture useful (*i.e.* the most positive result possible). This is strong evidence that the students, including those in the group that appeared to have lost interest, saw value in the strategy. The other questions of the teaching appraisal also showed a clear improvement in the students' perceptions of my teaching compared to the previous two years. For the question 'Overall, this teacher was effective', I scored 1.1 this year, compared to 1.7 in 2009 and 1.6 in 2008[1]. Also, a large improvement was seen in the response to the question 'The teacher gave me helpful feedback on how I was going'. This is an area that I have struggled with across all my papers, and I find this an encouraging result – not only is the strategy giving me feedback, but it is giving the students feedback too.

In some contrast to this, the appraisal questionnaires for ENEL312 were similar to those of the previous two years. However, I have always had better appraisals for ENEL312 than ENEL285, meaning that there has been more scope for improvement in my teaching for the second year class.

The free responses for ENEL285 backed up the finding that the questions were useful to the students. Half of the questionnaires returned indicated explicitly that I should keep the questions for next year. For example, "[keep] the questions, they really help". One student said that the lecture structure should be maintained and another that the time taken to explain questions thoroughly was worthwhile. Contrary to my fears, there were no complaints about the need to read material that was not covered in lectures. Indeed, there were no negative responses in relation to this teaching initiative, not even from those who appeared to have lost interest in the process.

Summative Assessments

Internal marks for both classes have been higher this year than in 2009. Specifically, for ENEL312, the median assignment marks this year were 5% and 8% higher than in 2009 for assignments 1 and 2 respectively. The assignments' questions were very similar between 2009 and 2010. Interestingly, the improvement was most marked among the top students; the upper quartiles having increased by 10% and 11% for assignments 1 and 2 respectively. Possibly using the multiple choice questions based around concepts is benefiting strongly those who are able to think well in these terms already, which normally are the top students; however, I have found no mention of this in the literature.

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[1] A response of 'always' from a student is assigned a score of 1; 'usually', 2; 'sometimes', 3; seldom, 4; never, 5; responses are then averaged across students.

Exam results for ENEL312 were very similar to the previous year. The median dropped by 2%, the lower quartile showed a gain of 6%, and, in contrast to the internal assessments, the upper quartile showed a drop of 3%.

For ENEL285, there are no comparable assignments between 2009 and 2010. My unexpected absence meant that I could not offer the support needed for the students to carry out the same assignment as for 2009 (namely preparation of a poster), so this was cancelled and replaced with something more traditional and straightforward. However, as with the 2009 cohort, the students undertook an internal test towards the end of semester. There was a small improvement from 2009; the median increased by 3%, with lower and upper quartiles showing a similar small gain.

The exam results were better than the previous year, with a 10% improvement in the median, though only a 6% and 3% improvement in the lower and upper quartiles respectively.

There was no discernable difference between the improvements shown by those enrolled for engineering degrees, and those for physics majors. Comparison of results between years carries two major caveats; first of all the year groups can be different in abilities, and secondly the classes are fairly small, meaning statistical variations are large.

Class discussion

While some questions students clearly understood, there were a few that provoked considerable discussion, and required substantial follow-up on my part. These were not always the ones that I anticipated the students would struggle with. In particular, for ENEL285, the questions relating to concepts such as quantization and wavefunctions generally showed a poor understanding from students. These concepts are initially taught earlier in the semester by another lecturer, and in previous years I have worked on the assumption that the students understood their earlier work. Experience this year suggests that this was a wrong assumption to make, and could have hindered students' ability to learn through my teaching.

In ENEL312 a similar problem applied to basic understanding of waves, which I have previously assumed students to have. Identifying these gaps in student conceptual understanding has been a successful outcome of this teaching strategy.

Outcomes

Overall, I feel that this strategy has been successful. I have realized that I have been overly constrained by the need to teach content instead of focusing on the core concepts. I note that this perceived constraint is in line with the findings of Henderson and Dancy (2007) who found that structural considerations, one of which is course content, has a major impact on how courses are taught. I am beginning to appreciate the value of instant assessment in lecturing, particularly at the start of a paper, and being able to adapt classes in response to this feedback. Results indicate that having a reduced content covered in the lectures, and leaving students to cover other material during their own reading, has not hindered their ability to do well in summative assessments; more likely it has improved it. Students have been motivated to work independently; I find this result encouraging. This approach has also had the secondary benefit of getting my students to talk in class more freely. This may be because they now see that open discussion is valuable and welcomed by the lecturer.

Reading of the literature associated with physics teaching has shown me that the manner in which physics is presented is critical to student learning. It has encouraged me to take a much less traditional approach in order to ensure that students grasp one concept before moving to the next. The fact that all the class (who completed the appraisals) found the strategy helpful has made me more aware that I can easily misinterpret students' non-verbal feedback. Students who appeared not to be engaging with the strategy were actually doing so, but in a manner different from my expectations.

I shall continue with this strategy next year, but will pay more careful attention to the ways in which students participate, and how my actions influence those. I shall also follow this year-group's progress carefully next year to see whether my approach helps them tackle third-year papers.

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