

## PREPARATORY EXERCISES ENHANCE STUDENT OUTCOMES FROM PHYSICS LECTURES

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### **Abstract**

Student outcomes from lectures are often less than ideal. In an attempt to enhance the lecture experience, short preparatory exercises were provided for students to attempt prior to lecture sessions. A successful trial of this intervention was conducted in a course in Engineering Thermodynamics in semester 1, 2006.

An extensive investigation of this technique was undertaken in semester 2, 2006, to evaluate the value of similar lecture preparation activities in a second offering of the Thermodynamics course, as well as for a course on the physical principles of Physiotherapy. An analysis of student response to this intervention suggests that while uptake of these voluntary exercises was quite low, those students who chose to use them found them useful and felt they had developed deeper conceptual understanding.

Given that lectures are still one of the most prevalent learning and teaching modalities in University education, the practice of offering students carefully designed preparatory exercises to enable them to gain more from lectures is a worthwhile and cost-effective way to improve student learning outcomes.

### **Introduction**

Although the value of traditional lectures for generating deep student learning has been regularly questioned (e.g. Biggs 1999), they remain one of the most common learning activities in most Universities, perhaps for economic as well as historical reasons. Evidence of poor outcomes from traditional lectures has led to a number of innovations attempting to improve student learning by encouraging active participation. These include “Peer Instruction” (Crouch and Mazur 2001), and the use of classroom response systems (Beatty 2006). Almost all of these active engagement strategies lead to improved student performance on multiple choice concept tests (e.g. Lorenzo et al. 2006), although little data appears to be available on the ways in which this ability prepares students for later study. The focus of these interventions is on improved conceptual understanding, but there may be little or no concurrent change in the student’s approach to learning, or problem solving behaviour. There is also a danger that students become dependent on the provision of similar activities, and their capacity for effective independent study may be reduced.

In considering other potential approaches to improving lectures, it may be advantageous to broaden our perspectives. Although there has been substantial research into student conceptual learning and learning approaches, there is less information available on the way in which students become “professionals” as they progress towards graduation. What can be stated with certainty is that they undergo an ontological change (i.e. their approach to the world changes over the period of their degree programme). Some parallels may thus be found between student development and professional development in teaching: for academics to effectively change their approach to teaching, a fundamental qualitative change in the way they understand and approach teaching is required (Trigwell 2005). This can be conceptualised as a development of their “ways of being” a teacher (Dall’Alba 2006). Similarly, students only meaningfully progress through a degree as their “ways of being” become more closely aligned with those of their target profession.

For both the cohort of Engineering and Physiotherapy students discussed in this paper, a graduate professional would be expected to independently evaluate their need for additional resources to solve a design/clinical problem, and decide on the value of available resources for assisting in this solution. It is therefore important to allow students to take responsibility for choosing how they use educational resources, as an element of encouraging them to develop as professionals.

The design of the present educational intervention was intended to allow students to better interact with lecture sessions through prior attempts at using the relevant concepts, while requiring them to self-evaluate the most effective way to use the material provided, and indeed, whether or not to use it. This should have similar outcomes for learning as other forms

of interactive engagement, but permits flexible use of resources and requires the student to take responsibility for using these to design their own programme of learning activities.

For each of the lecture sessions, an associated short voluntary question “worksheet” was offered to students as a means of assisting them to focus on the processes and concepts for that lecture. In the first semester trial of this intervention, many students used these exercises, and found that doing some previous work on the lecture topic allowed them to understand the lecture session more clearly. The format was a single page with four to six questions, with the brevity intended to encourage students to make serious attempts at the questions, without the excessive workload of previous interventions using textbook readings (which received limited response). Students also valued the worksheet as an opportunity to practice simple processes before being required to use these as part of more complex analysis. The worksheets were provided to students in downloadable versions (but not hard-copy) at least a week in advance of the relevant lecture session, and the ways in which they were intended to be used was explained in detail.

Questions were designed to encourage students to look up any unfamiliar content, as well as placing the ideas in a practical (and often reasonably complex) context. As an example, one of the questions included for the thermodynamics course (ENGG1050) is “Sketch a rough P-h diagram for water (include the saturation envelope), and indicate in which region/s an ideal gas approximation is reasonable.” This requires that students carefully identify the region where use of the ideal gas law is valid. Many find this difficult as the region is outside that covered by other data tables and P-h diagrams available in engineering practice. Sketching the diagram should help students realise that practical applications of the ideal gas law allow analysis of situations outside the range of these other data sources. The physiotherapy course (PHYS1160) focuses more directly on practical outcomes e.g. “Check the specifications of 3 or 4 home appliances. Is there any consistent relationship between the power rating of the appliance and the current it draws?” These are examples of two of the questions to which students responded with greater enthusiasm, as evidenced by greater participation in class discussions. Questions requiring abstract reasoning without a clear foundational rationale, and those requiring simply content or definitions were much less successful. This suggests that having a clear reason for the way in which a question is asked is important (Beatty et al 2006), and further, that it may be beneficial to communicate this rationale to students, so they are clearly informed about the processes expected, and the level of reasoning required.

### **Evaluation Methodology**

To determine whether students used the worksheets as planned, and how their learning was affected, students’ views were obtained via an anonymous online feedback survey. The response rate for both classes was 12% (14 of 116 enrolled for PHYS1160, and 47 of 388 for ENGG1050), suggesting that it may have been more effective to survey students directly in class. However, informal verbal querying of student opinion by tutors suggests that this data is representative of the views of the entire class.

The survey consisted of a short multiple choice item on students’ use of the worksheets, and an open question requesting them to give the reasons why they found the worksheets useful. A thematic analysis of responses to this question was undertaken to identify prevalent student views about the value of the worksheets. A third question was added for the survey of ENGG1050 asking students to compare their learning in lectures with learning tutorials.

An opportunity for general comments on the course was also provided, with some responses relevant to the worksheets and their effect on lectures. Detailed analyses of these will not be undertaken, but it is worth noting that almost all of the students in the physiotherapy course who responded to the survey were extremely positive about the value of lectures, whereas the view of those in engineering thermodynamics varied widely.

### **Results and Discussion**

The degree to which students used the worksheets is shown in Table 1. Combining the number of students who used the worksheets “most of the time”, irrespective of whether this was before or after the lectures, indicates that 50% of student in PHYS1160 regularly used the worksheets, whereas only 18% of those in ENGG1050 were regular users. This is despite the higher workload associated with Physiotherapy, and perhaps indicates differences in the learning culture of the two classes. There are distinctly lower entry requirements for engineering, so it might be assumed that these results suggest that the small extra workload associated with the worksheets only appeals to high achievers. However, a number of students who performed poorly on intra-semester assessment did regularly approach me to discuss their attempts at the worksheets.

**Table 1. The way in which students used voluntary worksheets**

Student use of Worksheets	Fraction of respondents PHYS1160	Fraction of respondents ENGG1050
Most of the time - before lecture	21 %	9 %
Most of the time - after lecture	29 %	9 %
At least once	29 %	46 %
Never used	21 %	36 %

Aside from the comparatively low uptake in ENGG1050, it is immediately apparent that students' use of the worksheets differed from that intended. Indeed, a greater proportion of students used the worksheets after the lecture, rather than attempting them before. Written comments on the same survey indicate that this was predominantly a way of "checking" their understanding after the lecture session, and ensuring that they hadn't "missed" any important concepts.

The general consensus from students in prior cohorts of ENGG1050 is that they have learnt most in tutorials rather than lectures. However, the survey data indicates that in this semester's cohort, only 25% of respondents thought they learned more through tutorials than lectures, with the majority (around 62%) indicating that they learned more from lectures, and a small but significant fraction (13%) suggesting that they learned almost all concepts *and* problem solving processes through the lectures. This significant shift in opinion of lectures cannot be solely explained by effective use of the worksheets, since only 18% used them regularly, but it is likely that the process of designing and implementing the worksheets influenced the way I present lectures, and where I placed most emphasis. Indeed, writing questions to help students focus on the central ideas would be expected to clarify in my own mind the structure and links between the concepts taught.

Although the survey question from which this information was gathered for ENGG1050 was not used for PHYS1160, the general comments for this course indicate that this group of students were even more positive about lectures than in previous years. However, reception of this course has consistently been positive, so the slight shift may not be indicative of significant effects from implementing the worksheets.

To further understand the value of the worksheets for student learning, the survey asked students to identify why those who decided to use them found them useful. Responses to this open question were categorised by the principal themes mentioned. The most prevalent response was that the worksheet questions highlighted the main aims of the lecture, and allowed students to think about the ideas beforehand (or re-visit them afterwards). Other advantages that were mentioned regularly, but with lower frequency were that completing the worksheets allowed students to concentrate on the ideas better during the lecture session, and that they assisted students to link ideas to their prior knowledge, as well as showing accessible practical examples of how the information/concepts were used.

These outcomes are consistent with the aims of implementing this intervention, in that students believe that their development of conceptual understanding and (to a lesser extent) problem solving processes during lecture sessions were enhanced. These results are similar to the use of more rigid interactive engagement strategies, but rely heavily on the student determining their own effective approach to utilising these resources. This would be expected to lead to large increases in understanding for some students, but less substantial average increases in results on assessment items. This was confirmed by results on the ENGG1050 mid-semester examination this semester, which showed a significant increase in the proportion of 'high' results (scores of 80% or higher were achieved by 14.2% of the class, up from 8-9% for previous semesters), indicating that those students who choose to put in the extra effort to use the worksheets do gain a more developed understanding. However, the average result did not increase significantly, since only a small proportion of students voluntarily took advantage of this learning experience.

Although the average results would have improved had all students been forced to use the worksheets, perhaps by allocating marks for their completion, I believe it is in the students' best long-term interests to leave responsibility for learning choices with the student. Clearly, appropriate encouragement should be given, and the positive outcomes of using resources such as these can be communicated to future student cohorts, hopefully motivating many of those students who currently feel that the resulting improvement in their learning isn't worth the extra effort involved. Those students who took the initiative to use the worksheet felt they had gained significant benefits from doing so, and this may

encourage them to pursue independent learning activities when given future opportunities, as well as sharing this enthusiasm with their colleagues.

### **Conclusions**

The provision of preparatory worksheet for lectures is a simple and effective way of improving the learning outcomes for students who choose to use them. Properly managed, outcomes could be further enhanced by engaging less motivated students through highlighting the gains other students have had from this intervention. If carefully designed, other forms of independent learning resources could also be provided with similar effectiveness. For example a research article could be provided weekly for critical analysis, and students expected to answer a generic set of questions with regard to each article, or students could be asked to try simple experiments at home and write explanations of the outcomes. In designing these learning resources it is essential that we be cognisant of the needs of students' ontological development throughout their degree. Thus, new learning initiatives should not merely aim to better teach concepts and processes (i.e. knowledge and skills), but must have a broader philosophical underpinning with the intention of assisting students to develop toward becoming effective professionals.

The results of this intervention highlight the danger inherent in allowing students to take responsibility for their own learning, in terms of achieving optimal results in a single course. However, if we do not require and assist students to take on this responsibility, they may not become effective professionals who are able to develop and learn independently. Students who do take responsibility for their own learning, not only use resources provided in creative and productive ways to develop their own conceptual understanding, but their positive experiences should constructively shape their future approaches to learning. By facilitating high levels of interactions between these students, and others in their cohort, the overall effectiveness of learning throughout and beyond their degrees will be greatly enhanced.

### **Acknowledgements**

I would like to acknowledge the support and encouragement of Jim Butler, and fruitful discussions with Gloria Dall'Alba and Margaret Wegener.

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