Teaching Fellowship Preparation Sciences

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Portfolio title: Adapting to your students: An evaluation of physics tutorials	
Portfolio word count: 10,507	Term of submission: Trinity 2015

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Adapting to your students: An evaluation of physics tutorials

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A portfolio submitted for the
Teaching Fellowship Preparation
September 2015

Covering letter

This portfolio is presented as an application for a fellowship with the Higher Education Academy through the Oxford Learning Institute's Teaching Fellowship Preparation Programme, covering the three areas of teaching practice:

Design of teaching Chapter 5 proposes a lesson plan for a series of four tutorials on optics for second year undergraduates, drawing on ideas and discussions in the preceding chapters (especially Sections 3.3 and 4.2. The philosophy underlying this design is discussed in Chapter 2.

Assessment and feedback Section 1.3 outlines the environment and assessments managed by the department while Chapter 3 evaluates the means by which I communicate with my students to influence change in their behaviour and learning.

Evaluation of teaching Chapter 4 discusses feedback received from my students and colleagues and Section 1.3 evaluates the current state of the physics course.

and the five learning outcomes of the TFP:

1. My teaching goals and values are discussed throughout the portfolio, but are the concentration of Chapter 2. The context of my teaching is outlined in Chapter 1.

2. Alternative approaches to teaching are discussed in Section 2.4.

3. Analyses of different teaching techniques are presented in Sections 1.3, 3.3, 4.2, and 5.2.

4. Educational literature is cited throughout. Of particular note, the four conditions to bring about conceptual change proposed by Biggs (2003) are discussed in Sections 1.3 and 5.2 while the seven principles of effective feedback from Nicol and Macfarlane-Dick (2006) are considered in the context of a tutorial in Section 3.3. A critique of Ashwin (2006) can be found in Section 2.2.

5. Evolution of my teaching practice and understanding is summarised in Chapter 6, but is represented in the structure of most chapters and the document as a whole. These consider my past practices, discuss new ideas, and then develop future practices.

Acknowledgements

I thank Paul Bateman for his useful feedback and discussions with respect to our observations of each other's teaching. The comments of Proochista Ariana and Kathleen Quinlan have been most influential on this critique. I am indebted to Rhys Jones, Don Grainger, and Amy Mason for their illuminating conversations.

Chapter 1

Physics in Oxford

1.1 Introduction

Teaching and learning are intrinsically linked processes. To teach successfully, you must learn from your students to respond to their needs. To learn successfully, you must teach yourself and your teacher what you understand. This dialogue is central to both building a deep understanding of a topic in a student and reinforcing or evolving the teacher's understanding it. It is thus important that teachers, from time to time, learn about their own teaching to reflect on what influences their teaching practices and to assess their motivations.

To that end, this report begins with an overview of the teaching and learning environment for undergraduate physics at the University of Oxford. With this context in mind, Chapter 2 discusses the development of my teaching philosophy. That framework will be considered with specific regard to communication with students (orally and in writing) in Chapter 3. The success of my techniques in achieving their goals will be evaluated in Chapter 4 by soliciting feedback from current students and my colleagues. My lesson plan for an optics course will then be revised in light of these discussions in Chapter 5 and some conclusions will be presented in Chapter 6.

1.2 Overview of educational environment

I taught my first tutorial only seven months after finishing my Master's degree with no specific training, advice, or oversight (due to a catastrophic staff shortage). Thus, my teaching practices draw primarily from my own undergraduate experience at Oxford University.

The undergraduate physics course at Oxford aims to give students a broad overview of all major fields of physics over three or four years. Two to four hours of lectures, which are technically optional, are organised each weekday by the department complimented by two or three hours of tutorials each week, organised by the colleges. Twelve days of laboratory work, completed within the department, are required by the end of each year.

There is substantial freedom afforded to the colleges in how the tutorials are presented but all appear to use the format traditional in the sciences. Briefly, students complete

problem sheets distributed by the lecturer, which are marked (or at least skimmed) by a tutor and then reviewed in a meeting with two or three students. In rare cases, tutors prepare their own problem sheets. Problem sheets comprise five to fifteen mathematical exercises to familiarise students with the common methodologies of the course while encouraging a discussion of the conceptual framework underlying them. Written discussions or explanations are common but limited to one or two sentences within a larger question. For a more detailed description, see Palfreyman (2001).

Though tutorials provide the lion's share of a student's contact time with university staff, they have no direct impact on the student's formal assessment[1]. The vast majority of the student's final classification is determined by written examinations at the end of each academic year. Students are required to pass the first year and need a 2.i in the second year to attempt the fourth-year Master's course (which approximately two-thirds of students do).

As is common in physics courses, a spiral curriculum (Harden and Stamper, 1999) is implemented:

First year teaches the basic techniques that are used to analyse natural systems. Due to their relative simplicity, these are only suitable for application to highly idealised circumstances (from which numerous jokes about 'frictionless vacuums' arise).

Second year develops these techniques towards more practical applications, though still in idealised circumstances, with the aim to produce competency in the fundamentals of all area of physics. This year is often considered the most difficult due to the sheer quantity of information to be learnt in the absence of a clear motivation or 'hook'.

Third year consolidates the techniques to investigate various natural phenomena. Course titles shift from processes, such as 'electromagnetism' and 'lasers', to realms of experience, such as 'thin film materials' and 'nuclear physics'. This is the first time that students study modern research (i.e. the mid to late twentieth century rather than the nineteenth).

Fourth year applies that understanding to current research. The final year is more broadly structured in that (a) the students are given their first significant choice of subject, selecting two from seven papers, and (b) the lecture courses are shorter (4-10 rather than 15-25 hours) but more numerous to provide a sample of the major research currently performed in that area at Oxford.

The content of the course is separated into distinct subject areas which represent historical divisions in the study of natural phenomena[2]. There is no explicitly stated purpose to any given subject, the presumption being that the student will eventually

[1] If the student consistently works below expectations welfare or disciplinary procedures may be implemented, but these are rare.

[2] A common critique of the Oxford Physics course is its historical structure. The route by which humanity discovered the functioning of the universe is not generally considered a useful organisation of knowledge but is a compromise between the structures encouraged by different fields.

appreciate the interconnectedness of the discrete elements (or, more cynically, do as they are told).

I understand the attraction in not justifying each course. Some of the best memories of my undergraduate education are when suddenly everything made sense. It wasn't that I spontaneously gained knowledge but that I now saw how it all fit together and could appreciate previously extraneous details. Such experiences are common among academics and possibly inspire their peculiar liberalism that self-motivated study and realisation are the best route to academic understanding (which is indescribably distinct from common understanding). From my reading of the literature, I do not see how informing students of the individual utility of a course of study, to the advantage of the majority that will take their skills into the wider world, in any way prevents skilled students from experiencing an epiphany.

1.3 Departmental learning objectives

The Oxford Physics undergraduate course describes its goals in terms of transferable skills, as became increasingly common in the UK in the 1990s (p.7, Toohey, 1999). The Undergraduate Course Handbook[3] states that the course is

> "designed to provide education of high quality in physics, in a challenging but supportive learning environment, which will encourage all students to develop independent and critical habits of thought and of learning . . . transferable skills related to communication, computing, and problem solving. [It's] aim is to ensure that, on graduation, all students will be in a position to choose from many different careers, and have the skills, knowledge and understanding to make a rapid contribution to their chosen employment or research area, and that those with the aptitude are prepared for postgraduate study in physics, and thus contribute to the vitality of UK research."

The Handbook then describes at great length the assessment procedures, recommended textbooks, and outlines syllabi for each subject area.

This is a behaviourist approach (Mager, 1962) to course intent and neglects the central aim of a physics degree as (I believe) it would be described by the majority of staff — to produce a student that thinks like a physicist, in that they approach and solve problems using the techniques of physics (see also Lattery, 2009). These include modelling complex systems and processes with mathematical operations, simplifying and approximating those systems to distinguish between dominant behaviours and perturbations, and observing those behaviours both *in situ* and in controlled laboratory conditions to validate the modelling. Such skills are vital for working in the physical sciences and other careers (e.g. the outlook of a management consultant could be similarly described by replacing 'processes' with 'businesses').

These two views of the course describe different aspects of an understanding (drawing on the concept of 'knowing' discussed in Bransford et al., 2000). Firstly, one should

[3] `http://www2.physics.ox.ac.uk/sites/default/files/2011-06-03/course_pdf_17928.pdf`, though this is only accessible within the University network.

be proficient with the theoretical and practical skills used to analyse the natural world. Secondly, that knowledge must be suitably organised so that it can be applied in unfamiliar circumstances. Such a division is common in educational literature (e.g. Nicol and Macfarlane-Dick, 2006; Ambrose et al., 2010; Coil et al., 2010). Their combination should bring about what Biggs (2003) called a 'conceptual change' in our students. He postulated that four conditions are required to achieve such a change. Students must

(1) be clear as to what they are expected to do;

(2) have 'a felt need' to do that activity (and, more generally, learn the concept);

(3) be able to focus on the task of learning rather than the task of being assessed; and

(4) be able to collaborate and discuss amongst their peers.

As the course stands,

- Tutorials and the collegiate system provide an ideal environment in which to foster (4) through the formation of informal peer groups that can self-compare and evaluate (Abercrombie and Terry, 1970). However, the tutor must encourage students to discuss problems amongst each other from day one to avoid a counter-productive, competitive environment.

- Tutorials also provide a chance to engage with students to develop and maintain (2) in a manner that the rest of the course does not. The tutor can provide real-world applications of a topic, providing a more meaningful context to students. Especially in such a dense course, it is vital to remind students why they are doing this work (and why others do it) beyond the mechanical solution of problem sheets.

- The unusual brevity of the university's terms and the breadth of the course make (3) exceedingly difficult. Though it may seem as if the disconnect between tutorials and examinations allows students to concentrate on learning, when students are only assessed by exams it is reasonable for them to expect their teaching to concentrate on answering exam questions over developing understanding. The learning aspect of a tutorial become subsidiary to examination technique.

- The Handbook clearly feels that it is achieving (1) through detailed descriptions, but in practice students do not feel cognizant of the actual requirements (OUSU, 2010).

In my opinion, substantially more project-based work would be beneficial to student learning as it could enhance components (1) and (3) by refocusing teaching from the factual content to the application of those facts (moving towards Biggs' constructive alignment of learning objectives with assessment tasks). Some project work is currently used, but the belief that we must wait until their final year for students to have sufficient knowledge to complete any meaningful research misunderstands the purpose of such work; the project is a learning activity not an assessment. Research conducted by

a first or second year doctoral student does not necessarily contribute to their eventual thesis, but builds familiarity with their field of study. Thus, projects should have undergraduates work together to combine their individually incomplete knowledge to achieve some real-world result. Though Elton (2001) provides a decent refutation of the idea that world-class researchers are world-class teachers, it is not unreasonable to expect them to be at least competent supervisors of learning[4].

Sadly, from my position as a tutor it is not possible to change the examination system, the content of the syllabus, nor the provision of lectures. As a casual tutor[5], it is also not possible to deviate significantly from the standard lecture-sheet focused tutorial. I only see students for a few hours and, as discussed at the end of chapter 5 of Toohey (1999), introducing students to different modes of learning is a lengthy process. A sudden shift to problem-based learning would likely be met with significant resistance from students. Thus, I must use the standard tutorial format but should focus more on problem-based discussion and less on correcting students' mistakes (while not outright abandoning that component).

[4]With the caveat that projects need to be designed as a teaching activity and not simply a compliment to the supervisor's research. There is no problem with students engaging in active research, but the purpose of the exercise is their learning not their conclusions.

[5]I am employed casually by several colleges to give tutorials on parts of the undergraduate physics course that their staff cannot cover for one reason or another. Most frequently, I provide cover for pa/maternity leave or staff changeover.

Chapter 2

A teaching philosophy

2.1 Initial aims

My teaching has historically had two primary aims:

- That students are capable of communicating their understanding of the course to the examiners in a manner which will solicit maximal marks.
- To engage the student's interest and enthusiasm by continually relating their exercises to real-world applications.

Students have in general expressed a desire for greater clarity in examination criteria (OUSU, 2010) and frequent references to examination technique provides a concrete purpose to their work, maintaining the attention of all students from the most avid theoretician to those that long ago resigned themselves to a future in accountancy. Good examination technique was encouraged in all submitted work, such as the thorough annotation of mathematics to make it easier for both them and their examiner to follow. In our discussions, I would indicate likely uses of a solution within an exam question. This satisfied the most basic concern of any student and addressed one of the more noticeable gaps of the curriculum — explicit instruction on study skills.

Having given the students a concrete motivation for the tutorial, I could then take advantage of Oxford's unique teaching environment. Students in large part think of tutorials as a forum to discover how 'best' to solve the questions (Ashwin, 2005), but that could be achieved more efficiently through typed, model answers. A tutorial can provide targeted learning to correct overt mistakes, provide advice on how to avoid them in future, and introduce alternative methods. Larger group teaching can do this as well, but each student will bring unique problems which become increasingly difficult to address as time (and their attention) is limited.

More importantly, I introduced the utility of their studies in current research, attempting to inspire interest both in the work at hand and physics as a whole. It is important to sustain the belief that they will grow beyond their current understanding or they never will.

2.2 Teaching style

Those aims and the style of teaching developed in response to the tutorials I experienced during my own Oxford undergraduate education. These could be divided into three broad categories:

Factual overviews These concentrated on the techniques of each question from the problem sheet. A student may be asked to outline a solution on the board, which the tutor would correct verbally, or the tutor would demonstrate a solution and ask for input at various points. This was a highly efficient, if intimidating, means of teaching the first year mathematics course (which is exclusively factual) but was unsatisfying in other courses. Even when the tutor's comments extended beyond the problem, these lessons felt more like school than university.

Tangential lessons These centred around the supervised completion of a problem conceptually similar to the work in the problem sheet but not actually on it. I found these tutorials pointless as I'd either already worked out the techniques or had no idea what I was doing. In retrospect, the intention was to invoke a cognitive apprenticeship (Collins et al., 1991) by going through the more difficult parts of the sheet with critique from the tutor, demonstrating and refining my knowledge.

Interactive lectures Somewhere between the previous options, these tackle the major errors of the students' work but are interspersed with (sometimes lengthy) monologues from the tutor[6]. Problems that multiple students had had difficulty with would be summarised on the board (either by the tutor or a student that had completed it), during which we would be asked for corrections. The tutor would comment on where the methodology was relevant in research and on the physical implications of the results. We would offer terse guesses to questions and, in the rare circumstance that we felt confident with a topic, a more vigorous debate.

A factual overview is tempting as an efficient means of conveying information, and when my time or enthusiasm are limited my teaching tends towards them. However, I have found these lessons enforce a rigid organisation of knowledge. If the student's issue is a poor awareness of their knowledge (in that they do not realise they can apply something they know), the factual overview can worsen the problem by presenting the solution without reference to their previous work. This experience is in line with the the second and fourth principles required to achieve understanding of Ambrose et al. (2010). It is not sufficient to provide students with tools and assume they will know when to use them.

In theory, the tangential lessons should illuminate the course in a new light, but I mostly left feeling I knew less than I went in with. Even though I had physically performed the tasks, the learning was alien. As Ambrose's third (and Biggs' second) principle states, without understanding the motivation for the task, I could not engage with it and, therefore, could not learn. None of my teaching appears to fall into this category.

[6] Hence my label 'lectures'.

I strive to replicate the interactive lecture style, as I found it the most engaging. Their limitation is that they cannot be easily applied to novel problems, limiting extension material to anecdotes and examples. In part because I found lengthy digressions very interesting as a student, my anecdotes frequently devolve into monologues, which may be dull or distracting to students. They gave me a reason to care about the techniques beyond simply passing exams, but as a teacher I must be aware of the needs of my students and not simply act as another lecturer presenting them with information to absorb.

These categories clearly overlap with the first three categorisations outlined in Ashwin (2005) and Ashwin (2006). As he found for scientists, my experiences do not include his fourth category — the two-way exchange of new ideas and understanding. I, however, strongly disapprove of his implication (from the hierarchical construction of the categories) that that manner of teaching is the ideal. The aim of a physics undergraduate degree is to produce students that think like a physicist. This manner of deeper learning does not involve creating new ideas and challenging old ones. A researcher certainly needs these skills but an undergraduate student is not in a position to present new ideas in the sciences as they would in the humanities. Science develops knowledge by producing and/or evaluating data in the light of current understanding. An undergraduate has neither the ability (or funding) to produce data nor the familiarity to understand its context in current research. The idea that a student could present a new idea during a one-hour tutorial in the manner Ashwin discusses and teach the tutor something about their field is preposterous.

What a student is capable of doing is presenting a better way of explaining a system to the tutor. The framework through which one conceptualises mathematical operations is very personal and influences the manner with which one applies knowledge to future problems. As Schwartz et al. (2004) discusses, the day-to-day work of a researcher does not frequently require explicit conceptualisation of knowledge and a tutor can easily have lost sight of this aspect of the learning process. Students must be encouraged to explain their reasoning, understanding, and conception of the tools we have taught. As students near the end of their degree, they should begin to interconnect the discretely taught courses. Ashwin's findings that no science students or tutors described tutorials in a manner consistent with his fourth categorisation should have elicited at least some discussion of this fundamental nature of science and its position within the tutorial environment.

Where Ashwin is correct is that a tutor's practices are a response to their perception of the teaching environment[7]. The prevalence of factual tutorials, and the tendency for discussion to descend into a lecture, is influenced by the sheer breadth of the course. A student can achieve an average mark by simply reproducing the fundamental proofs with a few extraneous discussions they found interesting enough to remember. The nature and pre-eminence of examinations provides little incentive for students or tutors to move beyond factual levels of knowledge. Examining more detailed understanding is considered impossible (or at least the use of thesis-based evaluation far too slow and narrow in scope).

[7]Though this conclusion is attributed to various papers by Prosser and Trigwell.

2.3 Generic learning objectives

This self-evaluation indicates that my previous aims focused too directly on the task at hand and not what I actually wished to achieve. I wish to train physicists. To me, a physicist

- breaks down complicated systems into components as a means to understand their past and future behaviour;
- can communicate that understanding of the behaviour without requiring the audience to understand the means by which it was obtained;
- can apply knowledge of one system to understand another while appreciating the limitations of that analogy.

As I only see students briefly, I cannot achieve these aims, but I can introduce this philosophy to my students and ensure that my teaching methods encourage students to engage in each of these three activities. Hence, in any course I teach, my learning objectives are:

- That students initially approach novel problems (both inside and outside of the formal course) by identifying techniques and concepts that may contribute to the problem's solution.
- That students can discuss what aspects of a problem have been neglected or simplified to achieve a solution.
- That students can communicate the importance and utility of the course to a uninformed but interested observer (for example, their mother or a professor of another subject).
- That students can apply the techniques of the course in both simplified and real-world applications.

The first objective is a straightforward statement of solving problems like a physicist in the commonly understood sense. The second objective emphasises an often overlooked aspect of that approach. The third objective generalises my first original aim, refocusing it on producing a useful, transferable understanding rather than aptitude for examinations. The fourth objective acknowledges that the understanding of physics I wish to convey and the examinations students sit are intrinsically connected — solutions should not be presented without a context while tangents should not be devoid of connection to the course.

2.4 Alternative methods

In the course of preparing this portfolio, I discussed with associates the teaching practice within the medical sciences, including an observation of a tutorial (see Appendix A.1).

The greatest practical difference in the teaching practice is the task set to students. The medical sciences teach through essays and place significant emphasis on research and familiarity with current research, reflecting the differences between a physicist and a medical doctor. Though the three points outlined above could be used to describe a doctor, much greater emphasis is placed on the third. The goal is to provide students with a broad base of knowledge from which they can diagnose unusual cases.

There is also substantial focus on the evolution of the medical knowledge base. Essays better allow for a broad consideration of a topic and inter-related concepts. Familiarity with current research will be vital to proper practice through a doctor's career. Conversely, the basic concepts of physics are mostly unchanged in the past hundred years. The details vary, but not at the level of understanding we aim to provide an undergraduate. What is most important is appreciating the fundamental concepts that underlie multiple topics. This was most evident in the contrast between how the subjects defined a first-class candidate. A truly superb medic would integrate a thorough referencing of literature into an expansive knowledge of a field. A brief question should elicit commentary on a variety of related areas, considering on how systems influence each other. Physics, on the other hand, values a student that can accurately evaluate the behaviour of a system, recognise the similarities and differences between different systems, and identify which details of the system are most and least important. Physics rewards a specific approach while medics encourage breadth.

The lesson I observed was certainly unlike any I had experienced. The work completed had little bearing on the lesson other than as an introduction, which was interesting considering the tutorial's fact-oriented nature. The intention appeared to be to review a large number of facts while relating them to their practical application in developing treatments. I had incorrectly assumed that a problem sheet covered more facts and details than an essay. The essay's strength appeared to be that it allowed the students to sample from a massive range. The quantity of information before them could never be covered exhaustively, so the essay allows the student to select a focus. The tutorial then expands the student's horizons, highlighting (what the tutor believes are) the most important aspects of the subject.

Though I would hesitate to set my students essays due to their lack of experience in long-form writing, approaching an extensive subject by providing the students individual freedom is intriguing. It appears most relevant to project work where students can choose their own path and multiple approaches are required to reach a conclusion. This would be best served by projects that ask students to assess the probable cause of some effect rather than collect some data. To take an example from my own research, it may be more useful to tell students that there are many ways in which pollution impacts clouds and ask them to determine if some of those processes are relevant in a data set rather than asking them to specifically assess the impact of certain affects in the data. In other words, project work could be posed more like an essay question rather than a problem sheet question.

Chapter 3

Communicating with students

3.1 Previous experience

Feedback was the principle aspect of a tutorial that I felt could be improved within my own education and, when I began teaching, I specifically did the opposite to what I had experienced. Though it varied from tutor to tutor, they provided feedback formally in three ways:

- Cursory, qualitative annotations to problem sheet work;
- Quantitative marks on mock exams at the start of each term;
- Reports at the end of each term, summarising the tutor's opinion of my performance over the term. These would often recommend work for the vacation.

Interaction in tutorials provided informal oral feedback.

I found this style of feedback unsatisfying. The clearest information, the reports, were provided at the end of term, well after I had stopped caring about work. It also felt unfair that the problem sheets, my main task, was accorded so little consideration by the tutor. I paid most attention to the mock exam marks as these were provided while I was academically engaged and functioned as a metric against which to judge my later work.

I better understood the rationale for this style of feedback from advice I received when I began teaching. I was told to look through a group's work for ten to fifteen minutes to assess which aspects of the problem sheet needed attention. The lack of detailed feedback on the submitted work would de-emphasise the specific problem on the sheet and focus the students on the general techniques used. Though I understand the desire to encourage students to look beyond the problem sheets, I didn't feel this was best served by neglecting the work they had done.

It has been reassuring to find echoes of my opinions expressed in the literature on effective feedback. The emphasis on what had been done wrong rather than how to do it better was described by many Oxford students (OUSU, 2010). The difficulty in making use of feedback that is disconnected from a student's understanding of the course (in my case, the problem sheets) is discussed by Boud and Molloy (2013). A comment in Nicol

and Macfarlane-Dick (2006) that the provision of numerical marks negates the utility of accompanying comments was especially resonant and their broader point that "intelligent self-regulation requires that the student has in mind some goal to be achieved against which performance can be compared and assessed" encapsulates my dissatisfaction with the feedback I received.

3.2 Present practice

In rejection of the feedback mechanisms of my own education, I initially provided detailed annotations to my students' work. That required several hours work, an unreasonable investment in the long-term, and my comments were poorly comprehended by my students. Through trial-and-error, I developed a system whereby I provide four annotations:

ticks where an answer is correct and/or would receive marks;

crosses where something is wrong or is inappropriate in the context of the question;

tildes where I do not understand what the student is trying to communicate; and

comments where I wish to briefly explain something.

The system does not use numerical marks in part because I personally found it difficult to apply an existing marks scheme consistently and in part because I had no external reference against which to produce my own. Rust (2007) makes the valid point that numerical marks imply that academic aptitude can be assessed to two decimal places. Considering the minimal standard deviation enforced on exam marks, this can encourage a compartmentalised conception of knowledge that is inappropriate in the context of lifelong learning. The concern of Liu and Carless (2006) that inter-student feedback is not objective because of their lack of experience seems misplaced considering there is no obligation that a teacher will have that experience either. The teacher's strength is that they should learn from their mistakes and, eventually, form an objective view.

My system requires the close interaction of the tutorial format:

- I must explain to the students what I mean by the three symbols. This is provided at the beginning of the first lesson I have with any group.
- Tildes indicate where the student needs to clarify their answer. This helps guide the tutorial to areas that require more attention and provides a useful reminder that marks are not simply awarded for getting a correct answer. More complex problems require one to convince the examiner that you *understand* a concept rather than simply remember a definition.
- My written comments are usually brief content corrections or explanations (in the classification used by Walker, 2009) of areas I feel won't be addressed in the tutorial.

Every few questions, I ask the students if they have any further questions about the material just covered. The most common response, other than 'no', is a request for further explanation of an annotation. This reassures me that the students engage with my feedback and hopefully understand what I have tried to communicate. However, it doesn't confirm the student has understood the feedback in a manner which will elicit positive change in their learning. Considering the feedback cycle of Hounsell et al. (2007), my current approach neglects the final step whereby students respond to previous feedback. It may be worthwhile to introduce an explicit review of the previous week's work to encourage the transfer of my feedback from lesson to lesson.

I use the annotations as a guide through the tutorial, asking students to keep their work open in front of them so I can see my comments. The aim is to integrate my teaching with an explanation my comments. For example, I may explain that we solve a particular equation by using a substitution, then indicate a student that didn't make it clear which substitution they used despite getting the correct answer, clarifying a "show working" comment. Another student received a cross, which I explain was because they misplaced a term between lines. Without this explanation, annotations would require written comments to be comprehensible and that seems an inefficient use of my time.

Considering how my technique has evolved over the years, it is clear that I have used a definition of effective feedback somewhere between that of Nicol and Macfarlane-Dick (2006) and Boud and Molloy (2013) — communication between a student and teacher that elicits positive change in the learning of the student. I can see from week to week how a student changes their approach to questions in response to my feedback and, comparing the work of students at the beginning and end of a course, I believe I am successful in improving the behaviour of students. It is less successful, though, in improving a student's understanding of more tenuous concepts.

Broad, conceptual understanding is slower to develop and requires a student to repeatedly return to a line of reasoning. My annotations are less useful in this context as, outside of the tutorial environment, their meaning will be constrained by the student's notes and memory of the tutorial. It requires them to be an active learner, using their opinion of my feedback and their own work to understand the work they have done and guide future efforts.

3.3 Discussion

Students have been highly positive about my feedback (see Appendix A.3.1), though they mostly praise the fact that I give thorough feedback as opposed to clear feedback. I also consider the system successful as, since its introduction, I witness more change in the behaviour of my students, particularly with respect to students' annotation of mathematics. Students that would initially submit a sheet of uncommented equations include minimal explanations by the end of the course. If I were to see students longer, these would hopefully develop further.

There is some concern that this verbal-centric feedback system may embarrass weaker students by repeatedly indicating their failures. Confidence building is especially important in Oxford, where many students have a difficult transition from being top of

their class to merely average (or worse). My approach is to target my interactions. I ask weaker students to present questions they have answered well while having stronger students carry questions that the whole group has struggled with. I also give weaker students more written, positive comments. The approach is by no means perfect. One student should not be allowed to dominate discussion nor dominate 'clever' questions and, though peer teaching is a powerful tool, one must be careful to ensure that the interaction is not a strong student demonstrating their superiority.

Nicol and Macfarlane-Dick (2006) argue that if a student has a different conception of what is required of them, feedback will be misunderstood and ineffectual. At a first glance, tutorial teaching appears superior because it can encourage a frequent and repeated dialogue between an experienced tutor and their students (as Ashwin (2005) would put it, they ideally exchange points of view and learn from each other). A poor tutorial is then one in which the perspective of the tutor dominates the discussion, as discussed at length in Elton (2001). However, this reasoning seems to imply that teaching in higher education is most successful when it resembles the supervision of postgraduate students, emphasising the individual work of a student with guidance from an experienced supervisor.

There are certainly aspects of supervision that are useful to tutorial teaching, but postgraduate study has explicitly different aims to undergraduate education. The former instils professional competence and distinctive excellence[8] while undergraduate education works towards more generically useful skills and understanding. The postgraduate student emulates their supervisor to learn a vocation while the undergraduate student does so to understand a topic. The postgraduate follows a path and explores its less-travelled branches; the undergraduate is shown how to find the path and speak with those travelling it.

To that end, a tutorials' greatest strength may be its formation of collegiate teaching groups from which to draw feedback. It is often stated that the best tutorial is one in which the students teach themselves and the concepts underlying effective feedback illuminate why. Considering some of the seven principles of Nicol and Macfarlane-Dick (2006),

- one students' work can be used to exemplify good performance to the group (1) and encourage self-belief (5);
- self-assessment (2) is developed as the students work together and realise their relative ability;
- tutorials intrinsically contain a dialogue (4). Even when the tutor simply lectures the students, the existence of a peer group provides a forum to better understand that tutor.

This is not to say that tutorials are inherently perfect. A competitive atmosphere between students will stifle their dialogue. Incomprehensible feedback can do similarly or foster incorrect understanding. To be fully successful will require significant mo-

[8]Whose assessment has distinct challenges from those discussed here, see van der Vleutten and Schuwirth (2005).

tivation and input on the part of the students, along with an acceptance that they will occasionally be wrong (and must learn from that).

3.4 Response

I am mostly pleased with my provision of feedback as it appears to elicit change in my students behaviour but two elements could be improved. Firstly, in written comments there should be slightly more emphasis on conceptual understanding. The tilde is a useful reminder to hold a discussion, but when the student returns to their work there is no guarantee they will remember the details of this discussion. Tildes should be accompanied by a short description of what information I was expecting and some hint as to where that can be found (i.e. "Was expecting some mention of boundary layers, as in Andrews Chapter 2"). This would provide students with a better appreciation in the long-term of what is desired of them and guidance on how to improve.

Secondly, students should be able to respond to previous feedback. The simplest means would be to ask at the beginning of each tutorial if there are any questions, concerns, or outstanding issues from the previous tutorial. However, students are unlikely to respond. My inclination is to more heavily emphasise that students can email me if they have any questions or concerns. This is still unlikely to receive much response, but at least allows for a feedback cycle. Better results would be obtained if I were to email students individualised feedback (e.g. provide a broad summary of their performance on each sheet) as, by beginning the conversation, I take the impetus to act off the student. It would also provide a private forum in which to provide feedback. The main drawback is the significant time investment and the fact that I don't always have useful comments.

Some exploration of how students can evaluate each other may be advisable. The literature has many recommendations, but none has appeared wholly satisfactory, especially in the short time frames over which I see students. I must foster communication among a collegiate group while monitoring it to ensure the interaction remains to their benefit. Again, project work could encourage this.

Chapter 4

Evaluating my teaching

4.1 Feedback from students

The colleges I have worked for have various feedback mechanisms. One course leader would informally ask if students found their teaching useful at the end of each year and simply not hire tutors that were described poorly. Most colleges require students to complete a questionnaire, covering all tutorials that year. This feedback aimed for a general overview of teaching at the college rather than specific feedback for an educator. The Academic Affairs Officer of one college's JCR organises voluntary interviews with each year and subject, asking about each of their tutors and providing individualised summaries. This is clearly a significant endeavour for that officer but is substantially more useful and relevant.

Quantitative feedback, in my opinion, is most effective at providing an average of student opinions. This is useful for a large group but with the sets of six students I see, the evaluation needs to be more individualised; a 'mean' of six opinions has little meaning. Comment fields could be added to questions, but these are frequently ignored. A primary advantage of using feedback forms is the mask of anonymity encourages honest feedback. In a group of six, a student likely suspects their style of writing or manner of criticism will identify them to the tutor.

For these reasons, and somewhat inspired by the interview-based evaluation mentioned earlier, I sought qualitative feedback from my students. There are limitations to this. Students are likely to feel uncomfortable providing negative feedback in person and, as a group, they are likely to agree with the opinions of their peers. Personal bias may also be at play, in that I may only note or recall feedback that fits with my opinions and expectations. In future, the use of an independent interviewer may be preferable to minimise these issues.

Impromptu interviews were conducted at the conclusion of collection classes[9] in Hilary Term for three courses. Group A covered second-year mathematical methods, group B third-year fluid dynamics, and group C fourth-year atmospheric physics. As

[9] A collection is a mock exam students sit at the beginning of each term reviewing the work of the previous term. They are reviewed in a class format with an explicit focus on the material and examination technique.

these courses had only four sessions, feedback during the course was considered less useful, in part because two hours is relatively little time to form an opinion on my teaching style and partially because each tutorial can be very different due to the changing content. The interview began "I teach because I enjoy it, not because of the money or the experience. Therefore, I want to know if I'm doing it well." We then briefly discussed:

1. What did you find useful about my tutorials?
2. Is there anything you feel I should spend more time on?
3. Did you think the balance of time between me and you could be improved?
4. Do you prefer tutorial groups of two or three?

Q1 was intended to explore which aspects of the tutorial were remembered. Group A was overwhelmingly positive, specifically appreciating my presentation of alternative methodologies without requiring their use, my willingness to explore their questions, and relating the quite technical course to the remainder of the syllabus. Group C were less enthusiastic, finding no particular aspect of my teaching noteworthy. The department provides model solutions for this course such that we had agreed it was unnecessary to go through the minutiae of each question. One commented that, "We're just looking for an idea of what all this is used for." Group B appreciated the detailed marks and conceptual discussions, as these had not been covered elsewhere. All groups mentioned my focus on examination technique. This confirms the assertion of Ashwin (2006) that the perceptions of students reflect the environment their tutor presents.

Q2 elicited the most unexpected answers. I had not noticed that my tutorials tend to run over time and one student felt that extending to 90 minutes would be useful (see Appendix A.3.2). Another in group B commented that my explanations were too fast to properly understand in the moment. I usually ask the room "Did you follow that?"; this may be the wrong question as group dynamics could encourage silence and assumes students can evaluate their own understanding instantaneously. Group C all felt they were unfamiliar with the standard against which they would be judged and desired more clarification. To my surprise, no students highlighted a specific section of their course.

I have been experimenting with different tutorial group sizes and Q4 was intended as a one-time sounding of student opinion. They had few, having only experienced one group size. I lean towards the use of three-person tutorials. The larger group reduces the emphasis on individualised feedback and provides greater scope for inter-student discussion. This was demonstrated in the tutorial that was observed by a colleague. Two students were absent, resulting in a one-on-one lesson. Despite the unique attention, the student tended towards factually-oriented questions. My attempts at more thoughtful questions were productive where the student had understanding but not universally. A three-person group increases the probability that one student is confident enough to speak on the topic. This could diminish the appearance that knowledge originates with me and encourage a greater self-identification with the learning process (though care must be taken to ensure one student doesn't dominate as that is equally corrupting).

The concern that my tutorials tend towards an informal lecture rather than a discussion inspired Q3. This point had been brought up by a colleague that observed one of

my optics tutorials (before this questionnaire was given; see Appendix A.2) — "Adam is too overly enthusiastic to give the answer [to questions] himself". Q3 wasn't successful as all answers were variations of "That's your choice," and "We wouldn't know what to say." The wording of the question appears to have been poor, implying a judgement of my ability to communicate rather than the quality of discussion. A better question may be, "Do you feel you had sufficient opportunity for discussion?" or "Do you feel you had reasonable control over the direction of each tutorial?" However, the answers force me to ask if my exam-oriented approach is making students see me as a secondary lecturer, providing additional information, rather than a supervisor of their learning.

4.2 Discussion

Though my student's feedback is positive, they tend to emphasise my concentration on examinations. It seems I have fallen for the trap discussed by Ashwin (2005) and Elton (2001). Problem sheets are inherently a factually-oriented approach to teaching. The process of completing work and submitting it for marking implicitly places the tutor as a figure of authority with a correct answer to provide to incorrect students. This was confirmed in the observations that by concentrating on questions the student had difficulty with, the tutorial is framed as a conveyance of information rather than a learning experience.

As my observation noted, my classes are "more about getting good marks than being a good physicist." I probe my students' abilities but my concentration on lengthy explanations and digressions asking only short-answer questions does not scrutinise their deeper knowledge. If I'm honest, this is because I don't expect my students to have one. 'I want my students to think like a physicist' means I want them to use the techniques of physics to deconstruct problems throughout life. I don't actually expect them to *be* physicists; only a quarter of students continue to research. To the remainder, physics is a set of questions whose solution result in a bit of paper that provides a job. I appreciate interested students and try to foster their interest, but don't assume that students have a personal investment in the course.

What this mindset has failed to appreciate is that their lack of interest does not preclude their gaining a more thorough understanding. Their motivation colours, but does not preclude, development of the desired skills and perspective. The question then is how do the sciences inspire higher level thinking?

My current teaching hoped to use anecdotes to relate the problem sheet to the larger context in real life. Feedback indicates this is not as successful as had been hoped. What can I do beyond that? In conversation with a friend with experience in educational theory, he suggested setting each student a topic to research before the tutorial and present over a few minutes. Example questions could be:

- What sciences questions have been investigated with this instrument?
- In what real life circumstances could this technique be applied usefully?
- How might this technique be extended to be more realistic?

These would explicitly draw the student's attention to deeper thought but without requiring the formality of a written answer. I already ask such questions in a tutorial but their answers are spontaneous and involve limited consideration of their knowledge[10]. Asking in advance may facilitate a more productive discussion as the students would be prepared. It also provides a forum for the more explicit instruction of the philosophical nature of science, as advocated by Schwartz et al. (2004); Coil et al. (2010); Hoskinson et al. (2014). Limitations are that I have to spend more time on preparation (to ensure I have an answer to the questions when the students have found or done nothing) and it isn't clear that students have the research skills necessary to obtain sensible answers (though obtaining them is a useful activity in and of itself).

This isn't to say that my current technique is without merit. The Ashwin categorisations are hierarchical and abandoning the factual aspects of problem sheets can dissociate the learning purpose from the practical problem (as I found in tangential lessons). Questions universally failed by the students need to be solved to appease the student's primary interest with passing exams. This, though, could be made more efficient through computer presentations for equations (though this is a substantial time investment).

It isn't guaranteed that students will actually respond to this new structure. It requires greater work from them, greater exposure to failure, and less certainty. Knowledge in undergraduate physics courses is not contestable. It's not complete, and understanding the limitations and caveats of the techniques is required to achieve a first class degree, but the techniques are ideal for solving the simplified questions set in examinations. This is why I hope to elicit discussion with questions tangential to the problems.

4.3 Moving forward

My teaching is well received by my students and continues to engage and challenge me. Due to an excessive concentration on conveying my own understanding of the topic, I have failed to probe and nurture my student's conceptualisation of a course. This was not evident from student feedback as the concentration of physics teaching on the solution of problem sheets implicitly frames teaching as fact-oriented, with the tutor a source of information auxiliary to the lectures and textbooks. The overview of problem solutions could be streamlined through the use of computer presentations to both allow the students to review them in their own time and provide more time for discussion. These discussions could begin from seed questions presented to the students in advance, such that their input in tutorials comes from a deeper, more considered manner of thought than the responsive, instinctual level I currently inspire. This will better serve the aim of teaching students to 'think like a physicist.'

[10]The Oxbridge tutorial system may lean towards educator-centred teaching but, in my experience, it is enormously successful at refining the ability to improvise intelligent-sounding thoughts — a highly employable skill.

Chapter 5

Course design

5.1 Second year optics

I shall re-evaluate a course that I taught for the third time this year — optics for second year undergraduates at Oriel College. The course is presented over 23 lectures in the winter term, building on a basic nine-lecture course given the previous year and somewhat complimenting the electromagnetism course of the previous term. I instruct the students over four sessions covering a 34-question problem sheet. Unusually, the lecturer provides only a single problem sheet and recommends subsets of these questions to be considered over four tutorials:

- Revision of the previous year's work and an overview of basic concepts;
- Diffraction gratings, a simple optical system applying those basic concepts to actual measurement;
- An introduction to the Michelson interferometer and Fabry-Perot etalon, standard instruments for analysing optical data;
- Application of those instruments to evaluating physical systems elsewhere in the course, primarily polarizing materials.

I have retained this structure because, with the addition of a few of the "optional" questions, it provides a continuity to the lessons. They gain a surface understanding of the mathematics describing a system through a set of basic questions and we discuss the implications of their results in that tutorial. The next set then seeks application of that system to a physics problem, requiring a deeper knowledge, while also beginning basic work on the next system. This structure evokes the learning cycle outlined in Fry and Kolb (1979) — experience, reflection, abstraction, and experimentation. By explicitly showing how the techniques introduced in one problem set develop from those in the previous, their knowledge can hopefully be given appropriate context and the students may appreciate the application of optics outside of the constraint of a syllabus.

5.2 Learning objectives and challenges

At the end of our time together, my students should be able to, in an examination environment:

- Use the techniques of geometrical optics and diffraction (identifying when each is appropriate) to evaluate the response of common optical systems;
- Explain the components and operation of a diffraction grating, Michelson interferometer, and Fabry-Perot etalon;
- Identify and quantify the practical limitations of these instruments and any analysis of their response;
- Apply (theoretically) these instruments to simple measurement problems;
- Conceptually and practical distinguish the polarisation states of light and describe how to generate each from any source.

Though not strictly a threshold concept (Cousin, 2006) as it doesn't hinder the ability to learn future concepts, students struggle with the concept of 'coherence'. Though they have been using the term since A-levels, when asked to explain what it means, they describe the properties of coherent light rather than a physical meaning for the term. Some time is spent in the first tutorial presenting a simplistic example (waves emitted by a vibrating atom) to relate the properties they are familiar with to a system they know. In the second tutorial, this is returned to with a brief discussion of lasers to assess how they have understood the previous explanation and correct residual misunderstanding.

Additionally for these students, I am the first tutor they have encountered outside of their college's permanent staff presenting the first tutorial they have had outside the grounds of their college. To provide some familiarity, I let the students select their own tutorial groups and see them in groups of three to take advantage of their existing rapport. I also begin each class by asking how they found the sheet and which questions they have particular issues with.

The greatest challenge is the student's unfamiliarity with practical matters. Though they have laboratory experience, those experiments were presented as a series of tasks and students have rarely appreciated their purpose. The knowledge is available but they are not aware of its relevance to this course nor how to utilise it. My previous efforts to explain experimental concerns have been successful in eliciting appropriate responses to identical questions, but there was little evidence that they had approached the knowledge in a deep manner. This seems an ideal topic to benefit from more problem-oriented approaches to encourage a reorganisation of their knowledge.

I could present the students with an unfamiliar real-world measurement problem (for example, how would you measure the quantity of nitrous oxide over Hyde Park Corner?). Context should imply the broad strokes of the answer, but it is important that I do not provide the solution. If they do not reach an answer in the time allotted, I should encourage them to research the problem so we can return to it in the next session. Following the lead of Abercrombie and Terry (1970), my role in that discussion should be

more like an unconvinced observer than a knowledgeable leader: asking for an explanation of each component (Why do we need a compensating plate?), wondering as to unforeseen consequences (What might stop this measurement from succeeding?), and probing the extent of the knowledge in a dynamic manner (Who would use this data?). This more closely resembles the use of scientific knowledge in actual research environments.

Previously, I responded to students' interests. This resulted in an increasing focus on examination technique and taking on the the role of secondary lecturer. This was well-received because it helped students to achieve what they saw as their final goal — passing exams. I shouldn't abandon such work, as the students are not wrong to concentrate on their assessment tasks, but I should provide an alternative (informal) learning activity that fosters deeper understanding. Considering the ways in which I can build an environment for deep learning:

- I have never avoided critique of the course and I should more explicitly use this to communicate our expectations to students. In revision classes, I try to explain the difference between a 2.i and 1 class student (and their exam scripts). This needs to be moved to my first encounter with the group. An explicit description of examination requirements both helps to create Biggs' first condition (section 1.3) and clarify that we can't examine all of the qualities we are striving to teach.

- It is unreasonable to expect students to deduce the practical application of an instrument on their own in under an hour. I could extend the existing 'describe the operation of' questions by asking students to research the instrument's applications. This would be set to a different student each week to be presented at the start of the tutorial. The other students could then discuss how the presentation relates to their own answers (enhancing Biggs' fourth condition). This provides an opportunity for skilled students to pass on their understanding and provides practice of presentation skills for all students.

- The students should be given more control of their learning. The optics course uses a problem sheet with more questions than need to be completed. I had been prescribing a subset of those questions I considered most useful. While some questions are exercises that need to be covered to ensure common misconceptions are addressed, others are application-based. I could allow the students to select some number of problems among a range, which may provide greater opportunity to have students 'teach' each other by explaining answers others did not attempt. This enhances Biggs' third condition by giving students greater control over their own learning and could provide the important 'felt need' of Biggs' second condition if the student happens to engage with the research topic.

- From the work of previous years, I would group problem sheet questions into three categories:

  (a) Bookwork questions where students reproduce work from the lecture notes. It is important to address difficulties with these questions as they are the

bread-and-butter of exam questions. Issues can easily result from a student being simply unaware of the existence of a technique or a more fundamental conceptual misunderstanding. Though these questions should be mandatory, I should avoid simply presenting a 'model' answer which students take as rote and instead concentrate on their specific concerns and errors I find when marking.

(b) Applications questions where students use the standard results to evaluate some system. These can be the straightforward input of numbers into an expression or an extension of the bookwork proof. In either case, students can fail to obtain an answer for numerous reasons. These questions certainly appear in exams, but are less predictable. These questions can be optional as experience with a variety of questions is more important than attempting any individual example.

(c) Complex questions that, though not necessarily difficult, are rarely answered correctly on the first attempt. Such questions are commonly placed at the end of problem sheets. An expectation has developed that only the strongest candidates complete these questions, which encourages most students to assume these questions are not aimed at them. Queries ask 'how do I do this' much more than 'what went wrong here'. It is important that students attempt such questions but it may be more beneficial if the student's answer is treated as preparation for a discussion in the tutorial.

5.3 Lesson plan

The intended course plan is for four tutorials, each of up to 90 minutes with three students. Each tutorial will follow the rough structure:

1. Presentation on the session's topic (me in the first session, a student thereafter);
2. Discussion of the presentation;
3. Application of topic to real-world problem;
4. Address student's questions on the mandatory work;
5. Consideration of optional questions.

The individual lessons will consider:

1. **Presentation**: Introduce myself (and my marking system) and the learning objectives (of the degree and this course). Then Q4, measuring the Fraunhofer diffraction pattern. **Questions**: geometrical optics and diffraction [Mandatory: 1, 2, 4, 7, 8; Optional: 3, 5, 6]. **Application**: What limits our ability to detect planets around a star? How do we identify if that planet could sustain life?

2. **Presentation**: (Q19), use of a reflection grating. **Questions**: Diffraction gratings [Mandatory: 9, 14, 15, 16; Optional: 10, 11, 13, 17, 18]. **Application**: How could you identify the presence of lead in glass? What limits your ability to make that determination?

3. **Presentation**: Q20, components of a Michelson interferometer. **Questions**: Using gratings and Michelson interferometers [Mandatory: (12), 22, 21, 28, 29; Optional: 23 and at least three short quantitative questions drawn from past papers]. **Application**: How would you monitor the quantity of nitrous oxide in Hyde Park Corner? Who would want to know this information?

4. **Presentation**: Q26, components of a Fabry-Perot etalon. **Questions**: Fabry-Perot etalon and polarisation [Mandatory: 24, 25, (27), 30, 32; Optional: 31, 33, 34]. **Application**: How would you minimise the glare for an office worker? A truck driver?

Students should complete all mandatory questions and at least half of the optional questions, as specified in the square brackets. A question number in round brackets indicates a complex question which students need to come prepared to work through in the tutorial.

My provision of feedback to the students does not need to be greatly changed, as the discussion of student's questions should continue to provide an opportunity to explain my comments to their written work. Considering the brevity of the course, feedback to me will continue to be solicited informally at the end the final tutorial. Due to the changes in my format, after the last lesson I would ask (by email) for comments on if the students believed that (a) my tutorials helped them to understand the subject, (b) they understood the practical use of the course topics, and (c) if they felt my tutorials made good use of the time available?

Chapter 6

Conclusions

I teach because I find it deeply rewarding. It provides a constant source of diverse and unique challenges that complement my research, my career, and my drive to learn. These challenges derive from the need to maintain a balance between the teaching environment, the tutor's intentions, the student's background, the material to be taught, and endless other influences on the ability to teach and to learn. Successful teaching and learning therefore require regular reflection and evaluation.

Both before beginning this seminar series and now, I am pleased with the quality of my teaching. I enjoy the work and my students appear to respond well to it. At a dinner this summer, I encountered two previous students. One commented that my class was the only one he managed to pass and the other said that she received her highest mark ever on the exam I taught. Two other students have gone on to research in my field. When aiming to give my students what they want, I appear to be very successful, but it is important to continually check that my style does not become entrenched and cease to serve my students. An ongoing dialogue through informal feedback is needed to ensure I fully address my learning objectives.

The greatest challenge in my teaching is therefore the environment. Assessment activities are poorly aligned with the desired learning objectives, producing an environment in which the ability to answer exam questions is the primary goal of both student and teacher. The increased use of group project work could improve the situation, but I am personally in no position to alter the structure of the course; such change requires several years and several committees. I must both satisfy the student's logical desire to perform in exams while also engaging them on a deeper level to influence their thought processes.

These seemingly conflicting goals are further complicated as I am only a casual tutor. Deviating from the accepted model of a tutorial requires that I hold the student's trust. It is unreasonable to expect that I could build that in under four hours while still achieving my other goals. Students desire consistency from their teaching, and yet a variety of teaching techniques are needed to find which environment is most suitable for each student with each topic.

The environment also affects the most valuable resource to teaching — time. I am employed as a researcher; my teaching is explicitly optional. For all the ideas I have developed through this portfolio, there is always the caveat "if I have the time." Research

commitments generally overrule teaching and both draw from a single pool of personal motivation. I must schedule my time to avoid such conflicts. Forward planning, such as this portfolio, can ameliorate the issue, but it is fundamentally unavoidable within the current organisation of teaching at Oxford. It is worth asking if the university truly values teaching, why it does not formalise teaching within postgraduate employment?

Regardless, tutorials provide an excellent forum with which to encourage deep learning when used appropriately. They provide students with a constant source of feedback and support from their peer group and a selection of tutors. That environment must be created and nurtured. When there is equality between the tutor and students, information can be discussed, reorganised, and conceptualised to improve understanding of the topic in both the tutor and the students. This is not the exchange of new ideas that Ashwin discusses, but an equivalent for education in the sciences.

However, the current physics course is poorly structured to take advantage of the tutorial. The presentation of solutions must not be allowed to dominate what should be a dynamic discussion. In my opinion, project work would be achieve a better constructive alignment of assessment with learning objectives. Projects would need to be designed as teaching exercises for groups of students and tutorials could then take on aspects of post-doctorate supervision, allowing the tutor to take the role of an uninformed but respected observer. Guidance and advice can be provided and ideas more genuinely discussed among equals in a group to develop understanding of topics.

From my position, implementing project work is impossible so the related but less ambitious idea of research questions will be attempted. Students will be asked to investigate an optical instrument, concentrating on applications and generalised descriptions to emphasise the fundamental concepts in the course instead of the mechanics of solving equations (without completely neglecting the latter). The success of this effort will need to be assessed through student feedback, drawing on the conclusions of earlier chapters. Then, evaluation can begin again so I continue to adapt my teaching practices in response to my students.

Appendix A

A.1 Feedback from my own observation

The observation was an interesting experience. While recognisable as a tutorial, it had a much more structured question-and-answer format than the focused discussion/lecture I am familiar with (as an undergraduate and, later, tutor). Though beyond your control, it felt like the fact you could only read/mark the essays after the tutorial significantly affected how the class was structured. Most of the lesson concentrated on assessing the detailed knowledge of the students about the chemical cycle discussed, which I feel could be more efficiently conveyed through written feedback on the essay. You provide additional factual details, such as alternative chemicals or caveats, and these appeared to be the moments the students were waiting for (based on their note taking) but spending twenty minutes reproducing a diagram they all clearly had in their essays felt slow.

I found it curious that you almost entirely ignored comments from the students. For example, about ten minutes in, one student made an incorrect observation, which two others immediately corrected. They began a brief discussion, which I understood as the first student accepting he was outnumbered and backing down, without necessarily appreciating why. The discussion was cut off, and not mentioned again, when the fourth student finished a sketch on the whiteboard and you began the pre-arranged line of questioning. This was one of many moments when the verbal comments of students, revealing their personal interests and weaknesses, were ignored and this general disregard for immediate feedback was the weakest point of the teaching in my opinion. It isn't inherently wrong, but more suited to large groups rather than tutorials.

The rapport with the students was immediately obvious and positive, with jokes passing between students and the tutor freely. For the most part, this appeared to maintain their interest and attention and was especially useful in the discussion of experimental techniques. That was clearly successful in connecting disparate areas of the student's knowledge and extending it to a novel context, while remaining clearly relevant to them. It further provided a firm ground from which to challenge the simple repetition of knowledge and elicit more detailed explanations, as required in examinations. It made the best use of the structure and resources available — a discussion complimentary to their essay, but beyond what they would have said.

However, the tutor's sense of humour bordered on insulting — out of context it could seem like bullying. Provided the students understand this environment (and they appeared to), this can be perfectly healthy but the tutor should keep in mind that some

students may find such confrontational humour very off-putting. Additionally, the student that gave the most factually oriented answers was called on least frequently for input and his comments and questions were occasionally outright ignored. From conversation after the class, this may be because that student is perceived to do less work, rather than any difference in ability. I see no problem with a tutor leaving a student to take very little from a tutorial environment, provided the tutor has ensured this lack of effort isn't a result of the student not working well with the teaching style of the tutor (i.e. the student's performance is poor across all courses).

A.2 External observation notes

Teacher: Adam Povey
Place: Barnett Room, Atmospheric, Oceanic and Planetary Physics, Oxford
Time and date: 4pm, 12 Feb 15
Format: 2 x 1-hour tutorial based on problem sheets
Subject: Optics, 2nd year Physics
Students: 2nd year Oriel College Physics. Three tutees per tutorial, expected.

Adam is prepared when I arrived at 3:45pm. He briefly explains that problem sheets are set for the students at the beginning of term and they work through sets of questions for each tutorial. Adam marks the answers and uses the student's answers as a way of assessing particular problematic areas.

I observe the first of two 1-hour tutorials covering questions 12-16, 18 and 19 from the problem sheets. One student arrives early. There are meant to be three (all male) in total, but the other two don't appear. Adam has marked problem sheets from all the expected tutees. After a period of perhaps 10 minutes of trying to contact the other tutees and find if they went to the wrong room (a different room was used for the previous tutorial), the tutorial begins with just the one tutee. I can imagine that a one-on-one tutorial is uncomfortable for both parties, but it doesn't appear that Adam is that bothered, and though the tutee doesn't appear to be totally relaxed, perhaps to an extent that his thoughts are clouded in response to questions, but he doesn't look as though he needs to run from the room and hide in a cupboard for a week.

Adam seems confident with the material, though will refer to some "ideal" answers he has prepared earlier. I don't think this is just that Adam is a practising physicist, but also that he an undergraduate and postgraduate Oxford-trained physicist. Some of the course will have changed over the time he took the course and now, but he has the experience of going through an earlier incarnation of the course in the Oxford setting. It would be interesting to see a non-Oxford-educated physicist giving the tutorial.

Adam sits directly across from the student. (It's only for question 19 that Adam uses the whiteboard.) He starts by asking the student which questions he found difficult and talks through the questions at the table with the student. The emphasis starts with coming to understand what different parts of the question mean. Adam then asks questions to draw out the answer out from the problem. These questions, as far as I can tell, are factual, probing or mathematical. They are to illicit response to give "model" answers to

the problems. Some of the discussion relates to previous tutorials to build upon prior knowledge. A certain amount of this discussion from Adam also references what examiners are looking for. This may be partially due to the "problem sheet" nature of the tutorial, probably common to this discipline, but I occasionally feel that the tutorial is more about getting good marks than being a good physicist. There are a few times where I think Adam could allow slightly more time for the student to answer, as though Adam is too overly enthusiastic to give the answer himself. Overall, Adam is more active in the discussion than the student. A certain amount of this is due to focussing on questions the student had difficulty with.

However, this is not one-sided. The student contributes to the discussion with his own questions. These are mainly around further clarification and explanation, not necessarily exploring new ideas. The latter may be due to the restriction to the "problem sheets" format. Another option is that this is not my area of expertise so may be missing anything particularly different, like being a non-speaker, I find it difficult to distinguish between Spanish and Italian. Saying that, there were parts I could relate to from my 'O' or 'A' levels as well as from a microscopy course I attended about a year ago.

As the tutorial started late, it overruns a bit while two students (one male, one female) for the next tutorial arrive. In the tutorial, Adam and the student have covered four out of eight of the questions. Questions 14, 19 and 15 were at the student's request. Question 12 (the last one covered) Adam covered as he thought it was one he thought many of the students had issues with.

The tutorial ends. The two new tutees from the next tutorial say that one of the tutees for the first session is ill, but they haven't heard about the other missing student. The following day, in response to a few queries on the matter, Adam emails me:

> "One of the tutees was ill, having sent me an email just after you turned up and I stopped looking at email. I've told him to drop around my office when he feels better if he has any questions.
>
> The other [from the first tutorial] emailed me this morning - apparently he forgot. I have been in touch with the staff at his college and they met with him this morning.
>
> There was one student missing from the second tutorial. He, though, apparently has a long history of disorganisation and missed tutorials that the college is apparently working on, but did not see fit to inform me of."

In my experience, I have not generally had issues with absences from tutorials. At the time of writing, I don't know if this is an unusual situation for Adam or not. Perhaps this is a bigger problem for some courses, such as physics, than others, like medicine. The latter has a fairly rigid and competitive career path. Students have to do well in the pre-clinical course to go onto the clinical training which then has to go well then practice medicine and the training that is required for that, and so on. The career paths for many other degrees aren't as clear-cut so perhaps the incentive to do well so early on it's as well established in some students.

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A.3 Examples of student feedback

A.3.1 St John's College Academic Feedback Session

Hilary Term, Tuesday, 21st February 2012

1. Students have noted that Mr Povey's marking is particularly good, as every problem is thoroughly marked, and as a result his tutorials are excellent.
2. Students feel that they do not, perhaps, have enough tutorials to cover all the material, but as a tutor Mr Povey has proven himself more than up to the task.
3. He gives students a good idea of what level they are working at, and creates an informal and colloquial atmosphere in tutorials which puts students at ease.
4. As he was an undergraduate at St John's, students feel that he knows the course very well and therefore has say the exam more recently and can give them more up-to-date exam preparation. Students feel they could ask him anything about eh course in an informal manner and receive detailed information when they need it.

A.3.2 Email from an optics student

Hi Adam,
I think most of us have filled out college tutorial feedback forms for this term, but these are pretty vague and since you asked I'll give some further comments.

- I like the way you focus on explaining concepts, rather than simply going through the questions (most tutors just do the latter). This is far more useful.
- I also think the amount of work you set each week was just right.
- In terms of group sizes, I think smaller is probably better (so pairs). But this isn't a massive problem and threes are just fine really.
- Tutorial lengths - we overran quite frequently, so perhaps extending to 1.5 hours would help.

That's all I can think of right now - I hope it's useful, and that the others get in touch with their own views.

Best wishes,
...

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