Reshaping large-class undergraduate science courses: the weekly workshop

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Abstract

I describe the rationale behind the introduction and practical details of implementing weekly workshops, recently introduced to replace traditional tutorial-plus-laboratory activities in a large introductory undergraduate physics course. The case for introducing these activities is made, together with their role in the course which has, over a period of several years, evolved into a blended mode of delivery integrating a substantial amount of online material whilst still retaining the crucial ingredient of 'presence' in face-to-face teaching. The effectiveness of the workshops is qualitatively evaluated.

Introduction and motivation

In common with many other introductory-level science courses taught in universities across the UK (and indeed beyond), student numbers in our introductory Physics course ('*Physics 1A: Foundations*') have swelled dramatically in recent years. Combined with this expansion is the widening diversity of student experience of prior study of the subject, together with their aptitude for pursuing it further (approximately 50% of our class size of 250 will be studying towards a degree in some flavour of Physics).

Not only are the pre-university 'on-entry' boundary conditions shifting, but so is the post-University 'on-exit' condition. Analysis of *First Destination Statistics* (FDS) for UK Physics graduates in 2003 indicates that of the 40% or so who entered employment, only 9% of these proceed to employment in scientific research, development and analysis occupations (http://www.prospects.ac.uk). In the light of these changes, we have begun to re-evaluate our teaching strategy for large introductory classes. This paper describes one part of the redesigned strategy: the replacement of the traditional 'tutorial plus laboratory' format with weekly workshops.

The workshops were introduced in the 2002/03 academic session, in response to two factors. The first was the consistent (and strengthening) student criticism of the laboratory programme (a view largely shared by the course teaching staff). It was seen by students as outmoded and largely irrelevant to the course material and for some a mechanical repetition of previously acquired skills. The second reason was a growing concern that the student learning experience in existing small-group tutorials (groups of approximately 12, run by a single member of staff or postgraduate tutor) was very heterogeneous. Some groups functioned extremely well, resulting in active engagement of the majority of the students. Others manifestly did not and became mono-directional worked examples classes, where the staff or postgraduate tutor went through answers on the board, often with worryingly little involvement from the class. Interestingly, the student view of these poorly-functioning tutorial sessions was substantially less critical than the laboratory programme. Tutorials were perceived as more valuable, even if what was going on in the tutorials was poorly aligned to the intended learning objectives.

Whilst not intending to devalue the importance of practical experience in the subject by diluting first year students' exposure to 'real' experiments, the course team felt that given the constraint of physical laboratory space and available slots in the student timetable, the optimal solution was to replace these two activities with workshop sessions, centred around group work activities, aiming to foster a wider range of skills more appropriate to the backgrounds and future careers of a large fraction of the cohort. As part of a growing awareness and understanding of the substantial body of literature from the US Physics Education Research effort, we have subsequently been comforted by their repeated recognition throughout the 1990s of the dangers of the 'clones-of-ourselves-culture': Redish (1994) has stated that, 'It no longer suffices to reproduce ourselves. Society has a need not only for a few technically trained people but for a large group of individuals who understand science.' In fact, the UK's National Committee of Inquiry into Higher Education (1997) 'Dearing' report has expressed similar views, making the point that programmes should include 'the development of general skills', including 'learning how to learn'. In fact, such sentiment has long been expressed by Physicists

> The development of general ability for independent thinking and judgement should always be placed foremost, not the acquisition of specialist knowledge. (Albert Einstein)

The role of the workshops and their place in the course

Understanding a little more of the background and work done elsewhere, we also now appreciate that what we have implemented here in replacing tutorials and laboratory work with workshops is towards the moderate end of the spectrum of practices that can be undertaken. Our approach is somewhat similar to that previously adopted and documented by McDermott and collaborators (McDermott, Shaffer and Somers 1994; McDermott and Shaffer 2001). Redish and co-workers (Redish, Saul and Steinberg 1997) have extended this formalism to include computer-supported laboratory activities that provide 'hands on' real experiences in kinematics and dynamics. We have not travelled quite so far down this road (principally due to space and time-constraints), but nor does our approach preclude such a development at some point in the future. In passing, it is noted that what has been implemented is a long way away from the other extreme of group work activity spectrum: i.e., those activities that are designed to replace lectures and the entire face-to-face experience is constructed around the workshop. Recent examples include the SCALE-UP programme at NCSU (Beichner and Saul 2003) and Technology Enabled Active Learning (TEAL) at MIT (http://web.mit.edu/8.02t/www/802TEAL3D/).

The main aims of the workshops are to emphasise the importance of group working (none of the activities are designed to be solitary) in the context of fostering a range of both generic and specific skills, such as problem solving, communication and the interplay between mathematics and physics. More specific details and examples are provided below.

In order to understand the role of the workshops in the course, it is necessary to describe their relationship to other learning activities of the course. Figure 1 illustrates the teaching and learning environment for the course schematically. It shows that the workshops activities are one of the main learning activities (one of the two that involve engagement with staff) and that these are supported via a variety and combination of 'real' and 'virtual' resources. Details of the rationale behind the course design and its implementation, together with issues relating to content creation, management and deployment have been reported elsewhere (Bates, Bruce and McKain 2005). Here it suffices to restate that the online resources form part of a coherent student experience, designed to complement and enrich (rather than supplant) the face-to-face 'real' activities. The collection of online material has evolved and grown over a period of some six years development to now comprise 1200 learning objects (or 'grains') of material, many home-grown, but some imported (such as Java applets, video clips of demonstrations (http://www.wfu.edu/physics/pira/index.htm) or virtual tutorials for mathematics support (http://www.mathcentre.ac.uk/staff.php) and external sites etc).

The workshops themselves embody that essence of 'enhancing the on-campus experience', gaining the best of both the face-to-face and electronic environments. They are essentially a taught class, but with extensive support from electronic material. The workshop programme is indicated in Figure 1 as one of the virtual resources: I now focus in more detail on the organisation, logistics and management of these classes.

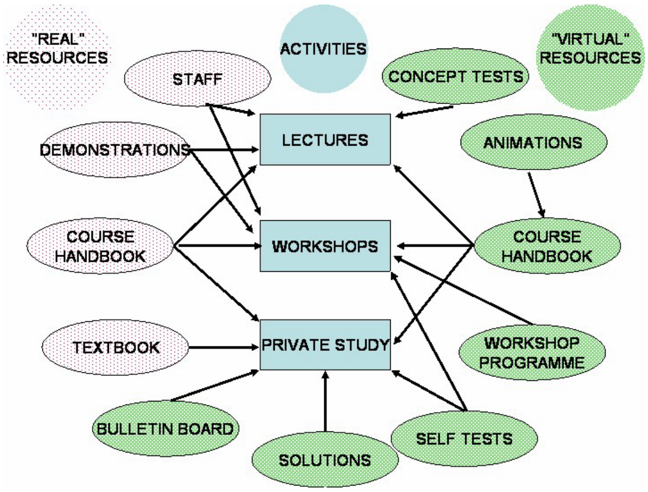

Figure 1. The teaching and learning environment, highlighting learning activities and the role of real and virtual resources

Logistics, management and activities

The physical space available to us for these classes, limits the attendance to a maximum of 60 (twelve groups of five). With a class of approximately 250, the workshops are repeated each day of the week other than Wednesdays, with students electing at the start of the course a day that suits the rest of their timetable. The staff overhead is correspondingly increased, as each class is effectively taught four times. Each class is attended by a Head of Class (a member of academic staff) and three postgraduate student demonstrators.

One aspect we have considered is the selection of student groups. Previously, we have encouraged groups to self-select, with an option to migrate in the first few workshops. For some groups, this has worked very well; for others it clearly has not. Student feedback indicates that the coherence/incoherence of their particular group was correspondingly the best/worst thing about the workshops overall. A strategy for dealing with groups that do not 'gel' prescribes that staff/facilitators can identify such groups and understand enough about how groups function to be able to be able to remedy the situation. The course team has considered specifying groups of mixed ability (classified by performance on, for example, diagnostic tests or school-leaving qualifications), but this idea has been rejected for fear of creating more dysfunctional groups than self-selection! As a cautious experiment, we currently randomly assign students to groups, offering migration to a different group as an 'if-all-else-fails' option. In addition, as illustrated with the cartoon in Figure 2, we spend some time indicating the many and various roles and personae that different group members can acquire over time (with some group members able to be 'chameleons' and adopt different roles in different circumstances or at different times).

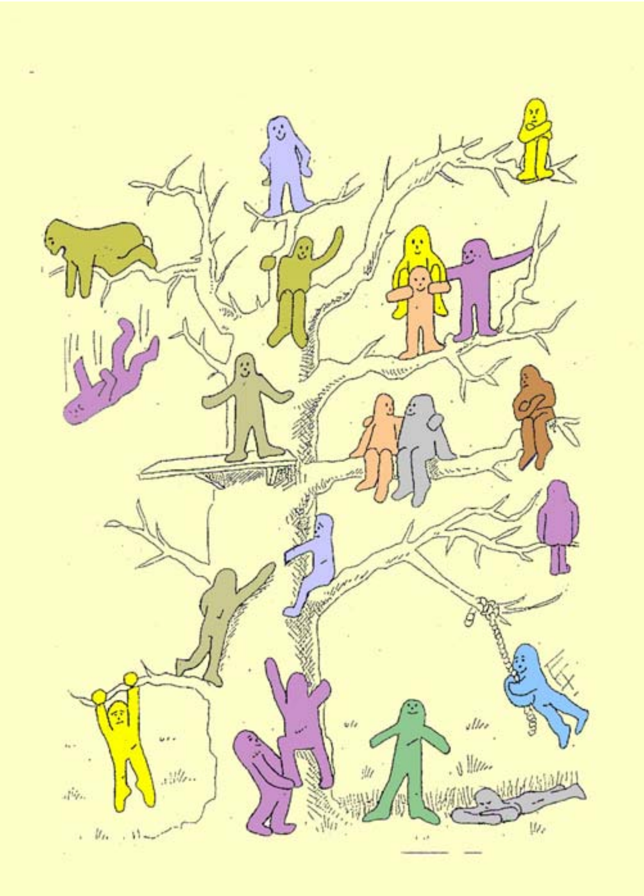

Figure 2. Group roles and personalities (used with permission from Dr Bill Byers, University of Ulster, UK)

The workshop programme of activities is delivered electronically within the online material for the course (all of which is delivered to the students via the University's Virtual Learning Environment (VLE) of choice, *WebCT* (http://www.webct.com/) though nothing is created or wedded within the VLE). The programme takes the form of a weekly-changing hyperlinked menu of activities, thus avoiding the paper nightmare of large groups of students and staff with multiple sessions.

Each student group of five is provided with a PC providing network access to the online resources (including the workshop programme) and a flip chart for group working and problem solving activities. A visual overview of the workshop setup and operation is illustrated in Figure 3. It shows the layout of (part of) the laboratory, a group of students working at a flipchart and a whole-class demonstration and discussion. A screenshot of a sample menu is provided in Figure 4, illustrating its 'menu' style comprising different activities. The menu items include (but are not limited to):

- **Problem solving** A substantial part (usually an hour of three hour workshop) is spent working on questions that test understanding of the course material. Students are encouraged to attempt these in outline as groups on their flipcharts with all contributing. Students are not necessarily expected to be able to cover all the questions relating to that week's work (the remainder are completed in self-study time). Nor are they expected to prepare copybook answers for all questions in the workshop session. The aim should be that at the end of the day the group has covered the ground well enough that each member can write a set of solutions, on their own, in their own time. Three of the 10 or so questions from each week are selected at the end of the session to be written up in full as 'assignment questions'.

- **Assignment feedback** Following submission of these weekly assignment questions, marked scripts are returned to students and the following workshop normally starts with a summing up of common errors or points to note from the previous week's assignments. Via the discussion board on the online course material, students can see a histogram of class marks for that week and thus evaluate their own performance in the light of this feedback.

- **'Challenge'** Whilst wanting students to feel that physics 'makes-sense' to them, we also want to challenge them with things that perhaps don't make sense immediately. Sometimes these will be 'real' demonstrations (as in the case of the one illustrated in Figure 3); sometimes they will be virtual ones (such as those imported as video clips from elsewhere (http://www.wfu.edu/physics/pira/)), illustrated in Figure 5. The problem is posed to students who then discuss within their groups to arrive at a consensus of 'what happens and why?'

- **Core maths skill** We try and impress upon our students that mastery in Physics at University demands proficiency in mathematics. The core mathematics skills that form part of this proficiency are occasionally practised explicitly. Conversely, we also try to stress the importance of being able to qualitatively describe things 'using words' and other activities do just that.

- **Banana skin** The subject matter of the course (the classical Physics of space and time) is fraught with student misconceptions (Hake 1998). This presents itself as the set of mistakes which every generation of students is prone to make. In an effort to encourage students to confront (and hopefully dislodge) them, we show them the 'banana skins' on which their predecessors have slipped.

One advantage of the menu-style approach is its modular nature, allowing activities to be removed and inserted from one year to the next with relative ease. In the current instance of the course, we are experimenting with a short section in most workshops to work on Problem Based Learning (PBL) activities. PBL has been defined as 'an instructional strategy that challenges students to confront conceptually ill-structured problems and strive to find meaningful solutions'. We have imported PBL problems into the workshop framework from the Project LeAP database (http://www.le.ac.uk/leap) and will evaluate student reaction to this small-scale pilot.

Evaluation and conclusions

Quantitative evaluation of the effect on student learning and performance following the introduction of such workshop activities into teaching programmes has been performed on the basis of pre- and post-instruction diagnostic testing (Redish, Saul and Steinberg 1997). Prior to the current academic year, we have not utilised diagnostic testing in this course, and can thus offer no comparable evaluation of student performance. Even if diagnostic testing is utilised, it is difficult to isolate the effect of one component of the course (such as the workshop). In our case, the workshops form part of a coherent programme of instruction. One quantitative evaluation that can be made is one of cost. There is modest start-up expenditure in equipping an already existing workspace with PCs etc; wholesale redesign of the learning space to be more suitable for such sessions would be prohibitive for many institutions. Staff costs in terms of creation and organisation of material need not be more costly that preparation of a set of lecture notes; perhaps less so if suitable electronic resources can be re-purposed and imported. Staff costs in terms of manning the sessions are certainly no more than with the traditional tutorial-plus-laboratory system, perhaps somewhat less.

Students are willing to provide detailed open-ended feedback on the workshop as a learning experience. Since the introduction of these sessions, students have been very (I refrain from using 'overwhelmingly') positive about the workshop experience:

'tutors were very helpful and knowledgeable and the challenges were not only excellent and entertaining but taught you real physics in action'

'having much smarter people at my table means they could explain lots to me and it helped me understand the lectures'

Working within a peer group was particularly valued by students. What reservations they did express were largely confined to the timing and physical infrastructure ('three hours is too long', 'desks uncomfortable'), problems with group dynamics (discussed earlier). Training of staff remains a key issue, central to the success of the workshops.

The workshop programme that I have outlined here continues to develop within the School of Physics. Possible future developments include the provision of a purpose-designed learning space for these activities, rather than 'making do' in a traditional laboratory. This in turn would open up the possibility to explore a wider variety of activities in the sessions, including re-introducing hands-on experimental or laboratory components. The methodology is applicable outside this discipline and variants on the theme could be applied to other disciplines within (and possibly outside) science.

Figure 3. The layout and operation of the workshop: (s) group work activity around the flipchart; (b) the laboratory layout; (c) class discussion of a 'challenge'

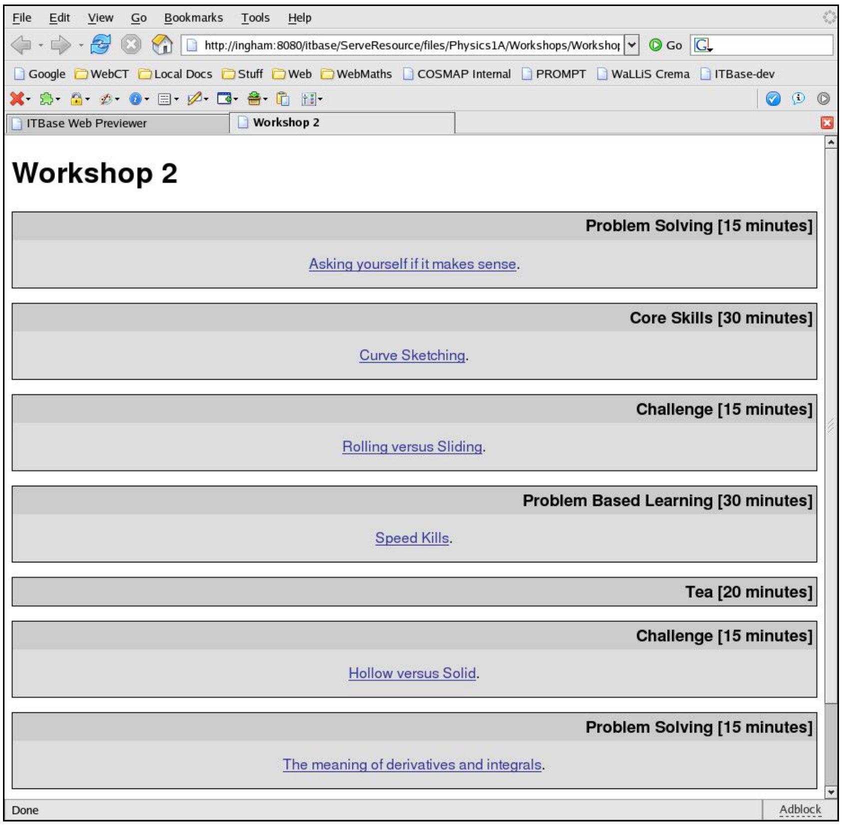

Figure 4. A screen shot of a sample workshop menu

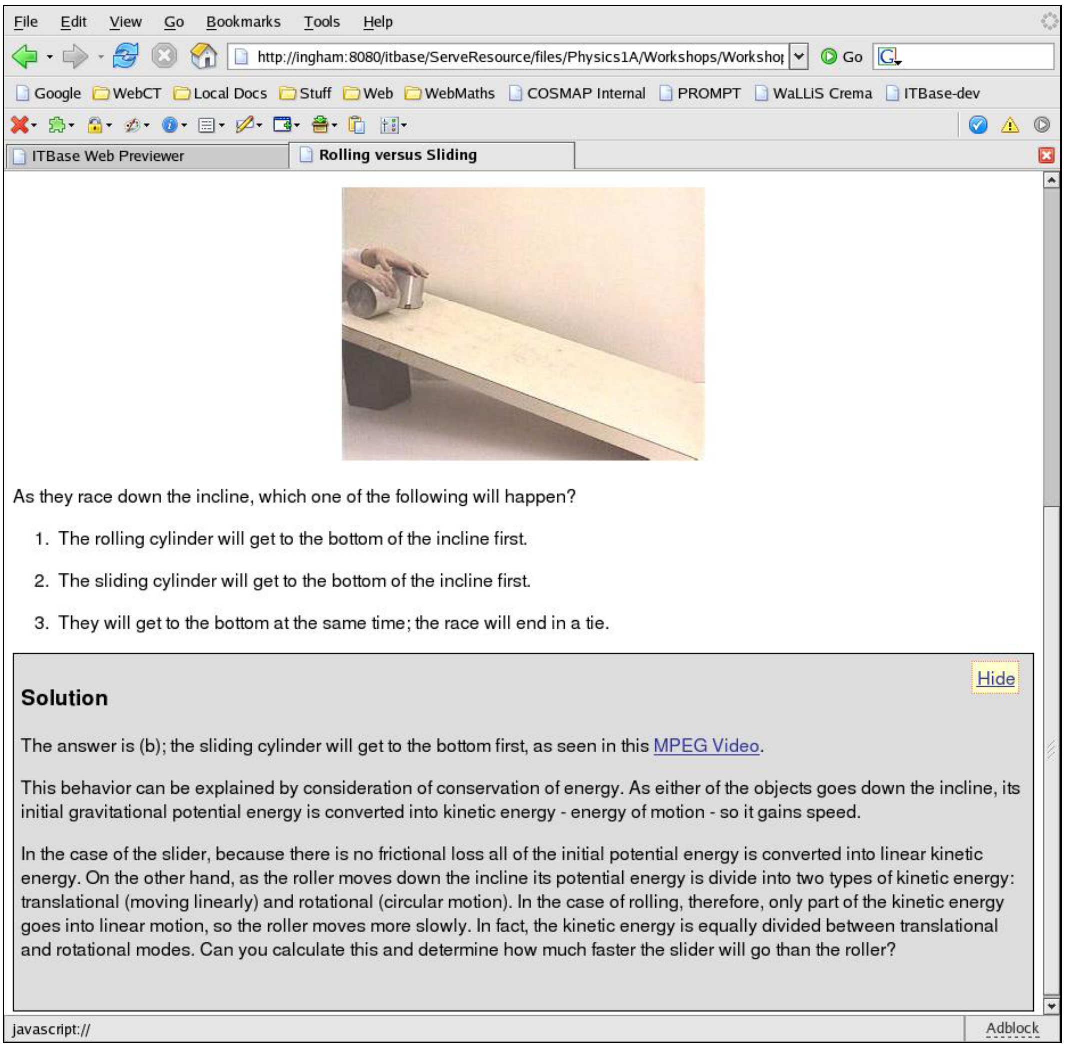

Figure 5. A screen shot of a sample workshop challenge

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