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Using a VLE to enhance a Foundation Chemistry laboratory module

Abstract

For the past few years, we have been experimenting with an e-learning approach to our introductory laboratory classes for first year students. Our overall objective was to maximise students' useful time in the laboratory. We considered that time spent with students gathered around a desk watching a demonstration is not an efficient use of staff or students' time.

It is well recognised that students' performance in the laboratory can be enhanced if they are familiar with the background of the experiments which will be conducted, hence the use of 'pre-labs'. We have been delivering our 'pre-labs' electronically by requiring students to work through a package before coming to the laboratory. As well as covering the theory and background to the experiment, short video clips have been included so that students will also have seen the experiment being performed. They should at least recognise the apparatus! The package concludes with a short assessment quiz which must be completed.

The packages were mounted on the University network using WebCT and meant that students could undertake the exercises at a time (and place) of their choosing rather than being confined to set laboratory hours.

This communication will describe the packages and our experiences as well as an initial evaluation of our approach. Although largely anecdotal, staff felt that they spent less time on more mundane aspects of laboratory work and more time discussing chemistry. Students also felt that they were better prepared for the experiments before they came to the laboratory. Some of the pitfalls and technical problems that had to be overcome will also be described.

Background and context

One thing that all lecturers teaching Chemistry in Universities would surely agree on is that practical work is an essential element of our courses. The acquisition of laboratory based practical skills is an aim and requirement of all chemistry based programmes^{1,2}. In addition, well designed practical work can stimulate students' interest, illustrate applications of concepts covered in lectures and enhance learning in other parts of their course. Unfortunately, the opposite can also be true; if experiments are repetitive and uninteresting or if students feel that they are 'following a recipe' in synthesising something or making measurements on a piece of apparatus, they can quickly become 'switched-off' and disillusioned. In addition, laboratories are expensive to operate and maintain and so it is important that they operate effectively.

As a department at Bath, we were fortunate in 2003 to move into a new, purpose built teaching building containing two laboratories, one each for 'synthetic' chemistry and 'physical' chemistry as well as a computational suite. The reorganisation necessitated by the move gave us the opportunity to reexamine our practical work, in particular that done by students in the early stages of their undergraduate Chemistry programme. At the same time, the University of Bath was piloting the use of *WebCT* and *Blackboard* as Virtual Learning Environments (VLEs) with which to support student learning. We decided therefore to experiment with using *WebCT* to underpin our Foundation Chemistry laboratory unit which is done by students in their first Semester at Bath.

This paper will describe our approach and experiences as well as an initial evaluation of running this new unit³. The module comprises a balanced programme of inorganic, organic and physical (including computational) chemistry although in view of the space limitations here, we will concentrate on the physical chemistry aspects for which the authors had main responsibility.

We wanted to update our classes to use the technology available to make them more efficient and effective.

Motivation and design criteria

The reasons for performing laboratory work in Chemistry at undergraduate level have been extensively discussed⁴⁻⁶. The overall aim of this 'Foundation Laboratory' module which runs for the students' first semester in Chemistry at University is to introduce the students to a range of practical methods and related skills which they will use in more advanced practical units later in their course. While other forms of practical are used in other parts of this unit and developed further later in the course, the initial physical chemistry component is expository in nature^{6,7}. It has been argued that little useful learning takes place in this form of practical work. However, we feel that it serves students well at this early stage of their course in terms of building confidence in performing practical work as well as to bring students to a common level of experience, independent of their pre-university studies. The detailed objectives of the physical chemistry aspects of the unit are:

- to reinforce aspects of the material taught in lecture units (at this stage mainly a revision and extension of pre-university work);
- to develop practical skills in assembling apparatus and accurately making, recording and reporting observations;
- to develop the ability to assess the quality and significance of measurements;
- to gain confidence in using PCs for calculating results and analysing data eg using spreadsheets.

Major emphasis is therefore placed on acquiring practical skills and analysing results. Inevitably in a unit taught early in the course, experiments may be scheduled before the background material has been covered in lectures. The experiments are therefore based on topics such as Hess's Law, pH changes and visible spectrophotometry (colorimetry) that are usually met in pre-university chemistry courses.

While our intake has expanded over recent years (by around 40% over the past 5 years), this was *not* the major driver for change and for the introduction of ICT (Information and Communication Technologies). We wanted to update our classes to use the technology available to make them more *efficient* and *effective*. Typically, classes of around 40-45 students are supervised by a member of academic staff with the assistance of two or three research student 'demonstrators'. Our overall objective was to maximise *useful* time for students in laboratory. In order to achieve this we wanted to:

- limit time that students spend waiting for routine demonstrations of eg setting up apparatus and/or waiting to talk with staff;
- eliminate students listening to class presentations that were unnecessary for them;
- allow staff to concentrate their time on students who need it most;
- speed up marking to enhance the feedback to students;
- encourage students to begin to take responsibility for their learning in the lab.

It is well recognised that students' performance in the laboratory can be enhanced if they are familiar with the background of the experiments which will be conducted. Most often, 'pre-lab' exercises are used to facilitate this^{8,9}. For our classes, we had previously used a short, paper-based quiz to indicate the extent of knowledge needed for each experiment.

The answers were discussed with a demonstrator before commencing practical work. The major enhancement offered by using the VLE was in this area of 'pre-labs'.

A major factor influencing our pedagogical approach is the variable level of practical experience with which students enter university. This depends on their school or college background and the type of pre-university course studied. Previously, many of our laboratory classes had started with a short introductory lecture and/or demonstration which students watched passively. This was often unnecessary for students with a good practical background while some others did not acquire the necessary information. We considered that time spent with students gathered around a desk watching a demonstration is not an efficient use of either staff or students' time. We therefore wanted to use the VLE to allow students to cover the necessary theory and background work at their own pace. In addition, there is ample evidence¹⁰ that if students are expending effort on the mundane aspects of experiments such as constructing apparatus, they can perform the experiment badly and hence miss the most important aspects. We felt that some familiarity with the apparatus to be used before coming to the laboratory would therefore help most students so that this was built into the VLE package. An additional local factor which encouraged this approach is that the vast majority (> 95%) of our first-year students live in rooms in University residences, in all of which network connectivity is available. Therefore, access to the necessary information was potentially available *whenever* the student wanted to access it without reliance on public-access or departmentally supplied PCs.

The unit content

In the first laboratory session, students were given an introductory demonstration lecture to help them navigate around the VLE. This was the only time that a traditional 'teacher centred' format was used in the course. The initial activity for a student first logging-on to *WebCT* is to watch a video on laboratory safety and to complete a mandatory quiz based on the video. We therefore have a traceable, electronic record of whether a student has undertaken safety training in addition to any paper based records.

To optimise the use of laboratory time⁹, we wanted students to undertake structured 'pre-lab' exercises outside formal teaching hours so that when they came to the laboratory, they would:

- be familiar with the background chemical theory involved in the experiment;
- be confident in performing any calculations involved;
- know why they are doing the experiment in a wider chemical context;
- have a good idea of the apparatus to be used and how the experiment is to be performed.

The first three of these can be achieved to some extent in a paper based 'pre-lab'. The last point though is difficult to illustrate in this manner.

To achieve our aims, each experiment has a VLE segment essentially involving four steps; a short introductory video to put the experiment into wider context, a short presentation to revise the chemical background, a video to show the practical aspects of the experiment and finally, most importantly, a short 5-10 question multiple choice question (MCQ) quiz

covering all three presentations. Students were required to undertake the quiz before coming to the laboratory (with penalty if not done). This allows them to gauge their level of preparedness to undertake the experiment and to get remedial help if necessary.

One of the physical chemistry experiments involves using Hess's Law to calculate the enthalpy change for the hydration of sodium carbonate from some calorimetric measurements. The approach that we adopted is illustrated for this experiment in Figure 1.

The introductory videos illustrate several aspects of thermochemistry in industrial and everyday contexts – for example a self heating can of coffee and a highly exothermic polymerisation reaction. They are kept to short duration (2 – 3

Given the objectives of the unit, we selected experiments that depend on chemical topics that would have been studied before coming to university. However, it may be some time since they were studied in detail so that students work through a short (4-5 min) *Powerpoint* presentation, included embedded audio, to reinforce their background. This can also be launched from within the VLE. For this experiment, a brief reminder of Hess's Law as it can be applied to this particular reaction is presented, as shown in Figure 2

Working through these activities *should* equip students with the necessary background for the experiments. However, all of these activities could be treated passively by the student or even ignored. The final part of the 'pre-lab' exercise is therefore a compulsory MCQ quiz. This covers the background theory, practical elements and any calculations

The screenshot shows a WebCT interface for a chemistry laboratory course. The page is titled 'CH10009 Foundation Lab- Phys Chem - Expt 1 - Enthalpy of Hydration'. The main content area is blue and contains the following sections:

- Introduction:** An introductory video to explain the background and context of the experiment can be seen here: [video icon].
- Background:** Before going on to details of the experiment itself, here's a short presentation on the theoretical background: [video icon].
- Apparatus and Techniques:** A video clip of with some details on the apparatus, as well as the techniques you'll be using, can be seen here: [video icon].

At the bottom of the page, there is a link: 'Now do the quiz (go to the link at the top of this page)'. A 'Quiz' button is also visible at the top of the page. Yellow callout boxes with arrows point to the video icons and the quiz link, with labels: 'Introductory, contextual video presentation', 'Powerpoint show covering background theory', 'Introduction to the practical aspects of the experiment', and 'Self-assessment quiz'.

Figure 1: An introductory WebCT page for a thermochemistry experiment

minutes each) and are focused so as to maintain student engagement. Similar videos are also used to introduce the experimental apparatus and methods that will be used. Some generic sequences made use of some of the Computer Video Consortium (CVC) resources¹¹ which we had previously used on laser disk as stand alone support in the laboratory. However, to maximise the usefulness, demonstrations of the experiments were filmed using the actual apparatus which students would use. Thus, they should be familiar with how to do the experiment (or at least recognise the apparatus) before they come to the class. All of the video sequences were recorded as .avi files and stored on our network server. WebCT was used to launch the *Windows XP Media Player* to play the videos, allowing students to pause or rewind the film and to watch the video as many times as necessary.

involved and so ensures that the student had engaged with each element of the package; the approach is illustrated in Figure 3. The administrative functions of the VLE make it very easy to check whether a student has attempted the quiz and completed the background work.

Feedback is provided if answers to questions are not entered correctly but this is deliberately minimalist. The point here is for the student to gauge their own knowledge. If they come to the laboratory with a secure knowledge base, they can perform the experiment more effectively and achieve its learning outcomes. If however, they identify gaps in their knowledge, students can get these addressed by staff before starting the experiment or performing calculations. In this way, staff time is concentrated where it is needed and not diluted across a whole class. While the VLE has the facility for recording student scores in these quizzes, we did not do so.

Students were required to attempt the quiz but not to achieve a required mark to emphasise that it was diagnostic in nature. However, fuller analysis of the data might indicate areas where improvements might be needed in order to enhance the package for future years.

In addition to the 'pre-lab' function, the extensive computer networking of our new laboratories allows us to make the information available during the classes. Therefore, if a student needs to check a problem, they can consult the background material instantly rather than possibly having to wait for a staff member to be available.

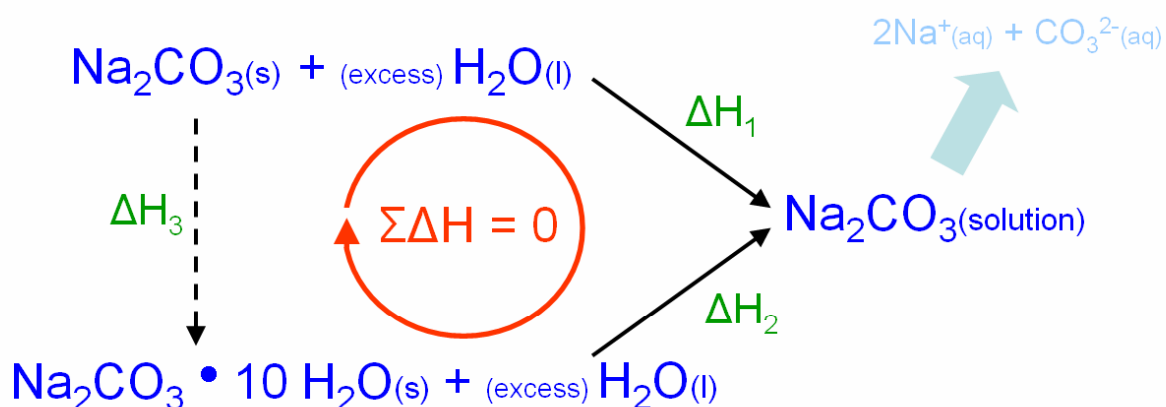
Further support for work in the laboratories is given by small structured presentations, for example on the estimation and treatment of uncertainties as part of the VLE package.

Evaluation and discussion

A simple comparison of students' performance on the unit with previous years is not possible since the organisation and assessment were extensively revised. This would not in any case be a good measure of whether we had met our objectives.

We invited feedback comments from students and conducted towards the end of the unit (prior to final assessment) a structured interview with all students in groups of 4-5. The interviews were not conducted by the staff teaching the unit so as to avoid potential bias. Their feedback showed that they understood the aims and objectives of our approach and felt that it was worthwhile. Most found the format more engaging than simply listening to a class presentation or watching video presentations in isolation from the experimental details.

Hydration of anhydrous sodium carbonate



Hess' Law means that we can calculate ΔH_3 if we can measure ΔH_1 and ΔH_2 .

GJ Price © 2004

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Figure 2: A reminder of Hess's Law

Students can access this as and when they are ready to process their results rather than in a class presentation at a time that may not be appropriate to their particular needs.

Inevitably, some thought there was too much background and some that it was too easy. Significantly, almost all students felt that they were adequately prepared for the experiment before they came to the laboratory.

Few students were negative in their comments about the style of the unit. An element of concern was raised by two students who felt that delivering material independently through ICT was rather isolating and did not convey the friendly, inclusive ethos that other aspects of the department's activities encouraged.

From the staff point of view, there was a noticeable improvement in laboratory performance in that less time was taken to complete experiments. Students were able to

A VLE is not strictly necessary. For administrative reasons, a VLE was not available to us last year and we delivered the material to students via a series of linked web pages. The results were similar although using the VLE made integration across a network easier (eg a single log-in for students) and the monitoring and recording functions were certainly missed. From 2006 onwards, the University of Bath has adopted Moodle as its VLE so that we are currently investigating how this package can be used to deliver the material.

The screenshot shows a WebCT quiz titled 'PhysExp 1: Pre-laboratory Quiz' by Gareth Price. It contains three questions:

- Question 1:** Calculate the number of moles of hydrochloric acid, HCl, in 100 cm³ of 0.2 mol dm⁻³ solution. (1 point)
- Question 2:** Why is the experiment carried out in a vacuum flask? (1 point)
 - a. To minimise heat exchange with the surroundings
 - b. To keep the reaction at constant temperature
 - c. To make sure that there is enough room for the solution, stirrer and thermometer
- Question 3:** (1 point)

The 'Question Status' panel on the right shows 6 questions, with 1 answered and 5 unanswered.

Callout boxes provide context for the questions:

- Question 1: Question to test basic ability in calculating numbers of moles.
- Question 2: Question relating to how the experiment is performed
- Question 3: Other questions address Hess's Law calculation, DH measurement and calibration procedures.

Figure 3: A self-evaluation quiz

concentrate on collecting data (and repeating if necessary) rather than in assembling apparatus. Demonstrators felt that the 'quality' of students' questions was better and more focused; rather than 'where does this bit go' type questions, enquiries concentrated on how to process the results and understand the chemistry. This is precisely what we had been aiming for. Staff were also able to distribute their time and effort more effectively by spending more time with students who needed additional help rather than answering routine enquiries from a large number of students. Also of significance were comments from staff running classes following on from the Foundation module. These suggested that students' performance was improved since they were used to completing pre-lab work and starting work immediately on entering the laboratory.

Of course, much of the preparatory work could be achieved using a paper based system to cover the context and fundamentals rather than one based on ICT. However, the use of the VLE allows a more coordinated presentation of the various aspects and, in particular, an illustration of the actual apparatus to be used. This obviates the need for much of the demonstration work previously undertaken at the beginning of classes. We estimate that some 30 – 45 minutes was saved in each session. This time was then spent at the end of experiments in discussion of the results with students in small groups; a more effective use of time.

The quiz and feedback functions of the VLE mean that students can gauge from their quiz results before coming to the laboratory whether they have a good understanding of the material and so know whether to start the experiment or seek further help. Using a paper based system, all students need to consult a member of staff before starting so that further time is saved. In principle, the VLE offers the facility for students to submit reports and practical results electronically. We trialled this but found there to be little advantage over students completing a paper proforma for marking. However, it did help in keeping track of assessments and in the unit administration.

Of course, there is a significant investment of time needed to set-up the packages. Filming, editing and recording the videos and presentations took around two full-time person-weeks. Transferring these and other documents into the WebCT environment took more effort. All of the various segments were stored in platform independent formats (.avi, .pps, .html) so that we are not reliant on a single VLE model. Overall the resource invested has, we feel, paid off in more effective running of our laboratory classes. Indeed, after we had put our system into place, we became aware that McKelvy¹² had operated a similar 'pre-lab' exercise using WebCT. Gratifyingly, our experience was similarly positive to his.

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The quiz and feedback functions of the VLE mean that students can gauge ...before coming to the laboratory whether they have a good understanding of the material

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