Prelaboratory activities to enhance the laboratory learning experience

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***Abstract**: First Year Chemistry at the University of Wollongong (UOW) includes compulsory practical classes run weekly for 10 weeks of each semester and completion of a prelaboratory activity is required to enter the laboratory for the weekly class. A* Flash *animation based prelaboratory program for First Year Chemistry is being developed and the Prelabs are administered via eLearning (VISTA). Prelaboratory activities vary, depending on the practical to follow. Typically the focus is a chemical principle or a particular calculation. Other exercises include visualising molecular scale events or virtual titrations with calculations. The Prelab usually includes some form of a flow diagram of the method. This paper describes the basis of the Prelab development to satisfy criteria regarding both enhanced learning in the laboratory environment and efficient tracking of four hundred plus students.*

Introduction

The importance of a laboratory or practical component to undergraduate chemistry is widely discussed but generally accepted. Some form of laboratory work is usually included in undergraduate curricula and there is certainly a challenge to ensure laboratory activities provide deep learning (Domin 1999; Elliot, Stewart and Lagowski 2008; Mbajiorgu and Reid 2006).

Laboratory classes can give rich learning experiences to students. They offer a bridge from the conceptual to the actual and from the molecular scale to the macro scale. They allow development of technical and manipulative skills for both qualitative and quantitative experiments. Students can work individually or in groups, usually with a low student to staff ratio. Most importantly, students have the opportunity to carry out their work in the presence of practicing scientists or PhD researchers, where, ideally, students can perceive and begin to take on our 'ways of thinking and practicing' (Hounsell and McCune 2004).

Preparation for laboratory classes is essential, to allow for meaningful learning. Laboratory classes can be stressful, where the student is required to combine conceptual and procedural knowledge, carry out certain tasks in a set limited time period and complete a laboratory report which may be assessed. Various methods of preparing students for the laboratory class have been tried and reported over the years (e.g. Rollnick, Zwane, Staskun, Lotz and Green 2001; Pogacnik and Cigic 2006). From these, one thing appears quite certain, that preparation with respect to knowing something of both the concepts and the procedures to be used is advantageous (Meester and Maskill 1995; Rollnick et al. 2001).

First year chemistry at Wollongong consists of two subjects, CHEM101 and CHEM102, run consecutively in the Autumn and Spring sessions. The student body is diverse and enrolments number around 450, with students in degree courses varying from nutrition and exercise science to medicinal chemistry and nanotechnology, as well as those enrolled in the general BSc program. A substantial portion of the students (35%, 2008) do not have HSC chemistry or equivalent. Although the majority of these students attend the two week Chemistry Bridging Course offered prior to the beginning of Session 1, there remains a small group (approximately 10%), the students in which have no Bridging Course and no HSC chemistry. The subjects are delivered as three hour lectures and three hours laboratories per week with tutorials also available. Practical laboratory classes are compulsory and cover 10 weeks of the semester with all students undertaking the same practical each week. Students do some practicals individually, some in pairs and some in groups. The laboratory manual for each subject includes the theory and procedures for each weekly experiment. Also in the manual is a detachable template for the student to fill in during the practical and this becomes the report submitted for assessment at the end of the laboratory session. Also included are spaces in which details from prelaboratory activities are to be entered.

Preparation for each laboratory is essential, as many of the students are relatively unskilled in laboratory technique as well as in theory. Preparation in the form of a set prelaboratory activity has been a long practice at UOW. There is a separate Prelab for each weekly practical. The intent of these prelaboratory activities is to ensure students have read through and considered the concepts and procedures given in the laboratory manual. The prelaboratory activity for a particular week must be completed in order to gain entry to that practical class. The Prelab is not assessed, but it must be correct to be completed. The previously used highly successful interactive Prelabs program was developed in the early 1990s using *Macromedia Director* (Wilson 1994). This program had come to the end of its life on account of software no longer being supported and editing not possible. However the principle of a tailored Prelab activity for a corresponding practical has been continued, with developments.

The Prelab system

The Prelab system now being developed is a series of interactive activities developed in a *Macromedia Flash* environment. The system is housed in the subject web site in the UOW learning management system, *VISTA*. Because students must complete the specified Prelab to have access to the practical class, tracking is required. Due to The Sharable Content Object Reference Model (SCORM) facilities being activated in *VISTA*, metafiles associated with the *Flash* files trigger a completion notice for each student in the gradebook of *VISTA*. SCORM is a system of specifications that allows communication between a learning object opened outside a learning management system (LMS) and that host LMS. In our Prelabs, the learning objects are the Flash animations which have the associated metafiles to give SCORM compliancy.

The setting for the Prelabs is the bench of a virtual laboratory, the design of which is based on our First Year Teaching Laboratory, see Figure 1. The content for each week varies depending on the practical details. A particular feature of a weekly practical – a concept, a calculation, a technique – is chosen to be the main component.

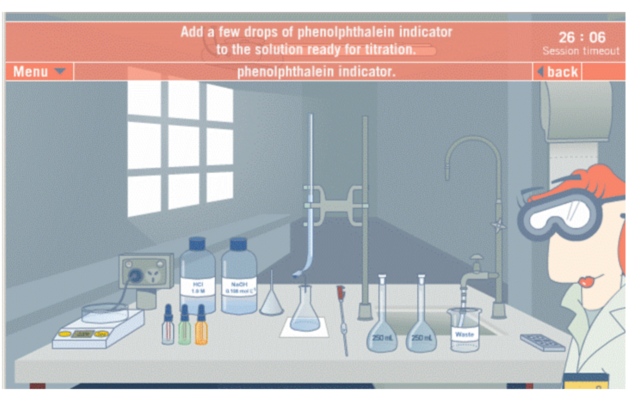

Figure 1: The Virtual Laboratory

The activities may involve any of: carrying out virtual manipulations (e.g., titration), visualising certain techniques in embedded videos, carrying out and checking calculations, answering questions or completing a flow diagram of the practical. Most importantly, students also write material from the online Prelab into prepared places in their laboratory manuals. This written material can include formulae, equations, structures, definitions, simple sketches, calculations and/or flow diagram details.

The partially completed flow diagrams in the Prelab are mirrored in the lab manual. The Prelab flow diagram is filled in either by ‘drag and drop’ or ‘drop down menu’. To do so the students need to read the laboratory manual procedure closely and choose appropriate options. Once the completed flow diagram has been checked as correct within *Flash*, students complete the hard copy in their manuals.

The development process

The overall design criteria were that web based media be used for the Prelabs and that the system be based in eLearning to allow for tracking of students. We also decided that Prelabs should have a homepage with access to various laboratory oriented learning objects, support materials and administration notes. It was also decided that each individual Prelab should be built around one, maximum two, major concepts required for successful completion of the corresponding practical.

It has been a core principle of this development that the virtual environment constructed and the laboratory equipment and activities carried out are authentic (see Figure 1). The activities have been designed by chemistry teaching staff. Staff responsible for the *Flash* animation development have watched experiments and taken numerous photographs in the laboratory to achieve this authenticity.

Macromedia Flash was chosen because of its flexibility in terms of interactivity and available features. The possibility of embedding images, animations or video clips, along with layering of objects and activities provide great potential for designing powerful learning activities (Whalley 2004). Interactivity needs to be more than just a few mouse clicks, as deeper involvement and mental commitment on the part of the learners occurs when they have to interact to solve a problem (Whalley 2004) or carry out a subject specific activity. Within Prelabs this is achieved for example, by carrying out virtual titrations or by combining Prelab and laboratory manual activities.

One of the design difficulties was addressing the issue of text. Students were known to ‘click through’ text of any notable length in the former version of the Prelab without reading it thoroughly. However a certain amount of information still has to be transmitted. In these Prelabs, text is given in as limited a form as reasonably possible, carried as voice bubble conversation between the teacher and the student characters, with the directive to read more in the lab manual. The possibility of students clicking through this text still exists, so questions are posed, either to the student character by the teacher or by the student character thinking aloud. The answer alternatives, with feedback, are provided as dropdown menus. The question has to be correctly answered to proceed. Students are thus forced to read the text closely.

The need to provide a consistent interface in the Prelabs for students working in this environment has been highlighted (Rhee, Moon and Choe 2005). This consistency is required to be addressed in several aspects of the interface. There must be uniformity of design in the various activities – calculations or flow diagrams or where to look for the next instruction. There needs to be uniformity in navigational possibilities, especially in the provision of moving backwards (‘back’ button) or in and out of layers (Gauss and Urbas 2003). Entry of calculation results for checking must also be consistent with respect to rounding of numbers and significant figures. This notion of consistency is very important because it gives the students confidence in how to use the interface so as to perform the subject specific tasks and achieve learning, without having to worry about the manner of their actual response.

Flash was also chosen for administrative reasons, due to its acceptance and wide application on the web. It was judged less likely to become redundant or superseded in a short time period due to web developments (Whalley 2004). Also included in *Flash* is the ability to use metafiles to communicate with a learning management system, to allow student tracking (arising from SCORM compliance).

Transfer of material between the laboratory manual and the Prelab

A key component of the prelaboratory activity is its integration with the laboratory manual. Thus the prelaboratory activity is demonstrated to connect directly with what will happen in the laboratory. This linkage also serves to encourage more than a superficial glance at the Prelab activity and the details given in the manual.

To successfully complete the flow diagram of the practical in the Prelab, the student must read the procedure in the laboratory manual in detail. Students also have to make notes of various sorts (and may add their own) in their manual, from the Prelab. So students need to interact with the Prelab more than superficially in order to discover which parts are important enough to be noted and transcribed. The calculations required in the Prelab also engender deeper approaches as students need to integrate data with principles. Some notes, especially formulae, are simply copied, in which case students may operate superficially. To counter this, it was decided that the Prelab would be the sole source of elements such as these to increase the importance of the activity.

Tracking students

It is required that the students be tracked to determine completion of the Prelab. The Prelabs are held within the learning management system, *VISTA*. When a student completes the *Flash* activity, a signal is sent from the *Flash* program to the gradebook in *VISTA*, allowing tracking of completions. Once in the gradebook, the data can be downloaded easily into a prepared spreadsheet format and checked for completion. If students do not have a result in the gradebook, demonstrators can check on what had been written in their lab manual. It is not intended that demonstrators 'police' the completion of Prelabs, only that they decide if subsequent action such as bringing this to the attention of the subject coordinator is required.

First pass assessment for further development

For further development of subsequent prelabs anonymous feedback was sought from students at the end of Session 1, 2008. Students were given the opportunity to write informal anonymous comments in response to particular questions on forms placed outside the Teaching Laboratory late in session. In addition some students (16) volunteered to take part in a focus group. This group, self selected, assembled in a computer laboratory and worked through six of the Prelabs with us, discussing their experiences and responding to various questions with written and spoken comments.

All written comments were then assembled and sorted to indicate areas of concern. The majority of comments were indeed favorable, but more importantly comments did point out areas needing attention to streamline and simplify the activities.

Responses to specific features of Prelabs: Flow diagrams
The most common comments concerned flow diagrams. These were greatly appreciated, but with provisions. The flow diagrams for Prelabs early on in the session were laid out in some detail. In the last two Prelabs, less space and less designed space were made available in the manual. A need for more detail and direction on how to make the flow diagram was requested. It appears some had not

yet developed enough confidence or understanding to draw up their own flow diagram. This begs the question of whether some were too dependent on having everything prescribed or some simply needed more practice and experience before proceeding independently.

Students also wanted a progress bar to show how far they had progressed through the Prelab. In fact such a progress bar present within its own part of the Prelab can be developed into a navigation tool. The navigation tool, if built as a tree for all parts of the Prelab, can also highlight other resources to students which they can find from anywhere within the linear activity. It is known that navigational aids can greatly help the weaker students (Gauss and Urbas 2003). Provision of progress bar / navigation tree will be developed in response.

Of particular interest was the response of the mathematically weaker students who wanted flow diagrams to direct them through the calculations (even when the steps of the calculation were laid out with units, they want a word commentary along side). See later comments on calculations.

Responses to specific features of Prelabs: Volumetric techniques

One of the important skills to be developed by First Year Chemistry students is volumetric techniques. These techniques cover the use of volumetric glassware and an understanding of where to apply particular levels of precision. Some students have already had exposure to these techniques at school, but they have not usually reached the point of producing quality analytical data. In CHEM101 the techniques are first introduced by the demonstrators in a introduction exercise and the techniques are described in detail in the lab manual. When titrations are carried out in a later practical, the corresponding Prelab highlights these techniques. Students find, much to their chagrin, that glassware items must be rinsed twice in order to proceed. Furthermore, specific glassware has to be rinsed with a corresponding specific liquid. This procedure has to be completed correctly to continue the Prelab. Although some responses indicated this to be tiresome, it was generally acknowledged as being a good reminder of technique details.

Feedback about titrations was generally favourable although two issues were highlighted. One concerned design: colours in Prelabs do not always allow easy reading of the virtual burette. The second was a communication issue, students need to be told to read the burette to the nearest 0.05 mL.

Responses to specific features of Prelabs: Calculations

Calculations in the Prelabs are set out in detail with units present, in order to model and promote best practice as is demonstrated in lectures and in textbooks. The students carry out the calculation both in their lab manual and online. In some calculations, the students are lead through step by step, with numerical data being checked before progressing. In other examples, only the final result is checked.

Calculations were generally found to be helpful. Some additional help was also requested, possibly in the form of a flow diagram, interpreting the calculation steps. This reflects a lack of mathematical skills, which severely undermines a student’s confidence.

Problems found and solutions applied:

- entering numerical data: get the correct significant figures by giving spaces to be filled in;
- the correct answer: avoid truncation issues by allowing an error band;
- keeping answers: if students navigate backwards, they should not repeat calculations; and
- indication of errors where the wrong calculation has been done. (This is most important for weaker students and will be addressed by providing linked help.)

Laboratory assessment results

The results of use of the Prelabs this year (2008 vs 2007) are difficult to quantify in terms of marks for laboratory reports. Changes were made to the laboratories and laboratory manual between years, the student cohort may be different, and staffing changes. This comparison remains inconclusive at this stage. Anecdotal comments from long term staff are generally very favourable, as it appears that students have been able to iron out some misunderstandings which have plagued past students based on those concepts being covered in the Prelabs.

Conclusion

The development of these Prelabs to date has been largely successful as demonstrated by favourable student feedback. Generally students find the Prelabs to be helpful in their laboratory learning. In addition they are intrinsically motivated to get more out of the Prelabs as a result of this positive effect. By integrating the Prelab with writing in the laboratory manual, the Prelab is directly connected to the laboratory activity. Furthermore scaffolded learning of techniques and concepts can be encouraged and students are actively involved in constructing their own lab preparation. However we have some issues to deal with in response to detailed feedback. This includes providing more information in flow diagrams of various sorts, providing support information for calculations, and tightening up on some visual aspects. The most important design development from here on will be the navigation tree, to show progress through the Prelab and to provide easy navigation to any resources in any part of the Prelab, independent of the essentially linear activity itself.

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