Preparing for the Chemistry Laboratory: An Internet Presentation and Assessment Tool

PAPER

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Video recordings have been made to prepare students for 43 different laboratory exercises carried out by students taking the first semester course in Introductory Chemistry. Each exercise-specific video includes an introduction describing the purpose of the exercise, details of the laboratory procedures involved, and representative calculations. Each video is packaged with a pre-laboratory quiz and the whole package is made available to students over the web using the WebCT system. The preparation of the package is technically simple (needing no specialised skills), easy to update, and inexpensive to produce (relative to the usage it gets). Both students and Teaching Assistants have been found to benefit from their usage of these packages.

Introduction

The value of laboratory courses in chemistry has been questioned on the grounds of both cost and effective learning for more than 20 years[1]. The first published attempts to improve student learning appear to have involved improvements to the structure of laboratory manuals and the way in which laboratory work is presented to the students[2]. However, Pickering describes pre-lab quizzes or pre-lab talks as "the classical way to prepare students [for laboratory work]"[3], thus implying that the importance of proper preparation was well recognised by 1987. One example of a pre-lab quiz was described by Kolodney and Bayly[4]. Merritt et al[5] introduced a requirement that students prepared themselves actively by submitting an 'experimental plan' for the instructor to evaluate before they carry out laboratory work. By 1997 Johnstone[6] argued that there is "*no point in putting a student into a laboratory without mental preparation*", and that "*the nature of the preparation has to be as carefully thought out as the course itself*". Clow[7] has presented the virtues of computer-based pre-labs, of which one example has been published by Nicholls[8]. Others have experimented with the use of videos. For example Joesten produced videotapes for students to use for pre-laboratory instruction, but subsequently dropped the programme because of the constraints on students' time[9]. Rest has produced a series of high quality videos of a range of common laboratory techniques, and these are published as videodiscs[10]. The advantage of this technology is that it is possible to define and select any desired sequence using a bar chart reader, and according to Rest[11] the video discs are widely used throughout the UK as an adjunct to laboratory work. In at least one case, clips from these videos have been incorporated into packages designed to support the teaching of a first year laboratory course in physical chemistry[12]. These packages are delivered by CD-ROM and incorporate theory, worked examples, and a computer-marked test.

Students at Georgia Institute of Technology are no different from others in that they need to be mentally prepared for their laboratory work. Two particular aspects of the first year semester course on Introductory Chemistry do not apply to most examples of pre-lab work quoted above, and merited special thought. One is that the number of students is in excess of 1400 during fall semester and the laboratory instruction is spread over a 15-week period. During the semester, each of the 1400+ students completes 21 of the 43 exercises in the laboratory manual. Each student attends one three-hour lab session in each week of the semester giving a total of 13 sessions. In order to fit this number of students into the laboratory, they are allocated to one of 75 separate sessions held each week so that the number of students present at any time is 20 – 24 (there are three different lab sessions on each of five days, and these run in five separate laboratories, giving a total of 75 sessions). The students are supported by one graduate Teaching Assistant (TA) in each session. The second unusual aspect of the course is that at least half of the TAs who teach the course are not native to the USA and their first language is not American English. Many of these TAs may have never previously carried out, or even come across, the particular laboratory exercises on this course and therefore need training.

It seemed that a web-based package would be the most efficient way to deliver material suitable for both training TAs and also preparing a very large class of students. Analysis of the needs of both groups of learners suggested that an effective pre-lab experience for each different laboratory exercise would

- explain the purpose of the exercise and review background theory
- demonstrate the procedures to be used
- provide help with the calculations
- provide feedback for the users on their level of preparedness
- provide access for the students to the instructor so that they could raise queries.

The WebCT system seemed to provide the specification necessary to deliver all these aspects of pre-lab work. WebCT

is a commercially available product which "offers colleges and universities a total solution across the learning enterprise by (a) providing faculty with the best tools for building online curricula; (b) connecting students with an integrated Web-based learning environment; and (c) supplying publishers an ideal platform on which to provide the richest variety of content"[13]. The Georgia Institute of Technology holds a site licence for this package, so that it was immediately available.

Methods

The material was planned to exploit the availability of two servers at the disposal of the faculty. There was a WebCT server to create, host and archive campus courses and a Real™ video server to host and archive html and real data for multi-bandwidth streaming. Fifteen three-hour laboratory sessions are scheduled each week and one site for each was placed on the WebCT server. Each of the sites is a copy of one template which has been archived for use as a backup. These sites are maintained by a departmental 'web master' and include the 'Instructor's Home Pages' which is a hyperlink to the Chemistry Department server and the individual instructor's materials (including biography, current research, publications, course syllabi, homework assignments, old examinations). The student also has access to a link to the glossary from the currently used textbook[14] and to an image database with images scanned from the textbook to serve as visual references (provided with permission of the publisher). The use of bulletin board tools allows students or the instructor to ask questions or to speculate on techniques and calculations. Useful as these resources are, the main part of the pre-lab package is accessed via 'On-line Pre-labs' which provides a path within WebCT that takes students to a table-of-contents; this lists the pages which show each week of laboratory work for the semester. Pages within this path contain the pre-lab work for a particular week's work and includes video material and quizzes.

Web-ready pre-laboratory videos were recorded with a JVC .5" IT 3-CCD S-VHS camera, a JVC S-VHS recorder/player deck, a Bogen™ 3068 Universal Cine/Video tripod with 3066 fluid head, and a Lowel™ Tota/Omni 3 light kit with 450-watt bulbs. The material was edited using Adobe™ Premiere 4.2 software on a Macintosh™ PowerPC 9600/233 with 160 MB DIMM, 4GB internal HD, 4GB external SCSI disc array (since upgraded to 64GB), a Targa™ 2000 Video Card, and an Apple™ 1710 17" color monitor. The edited material was encoded using Real Producer Pro® which enables it to be streamed at 200 kilobytes per second (kbps) for use on the campus local area network (LAN). Over 90% of the freshmen live on campus and all are required to bring their own computers equipped with internet access hardware and software. Since every dorm room on campus is wired to the LAN, students can access the pre-lab sites at any time of the day or night. By fall of 2000 it should be possible to encode the videos into multiple bandwidths for viewing from off campus as well. Once this has been done, students may access them from any place in the world with Internet access. Until then, computer clusters are available with headphones and web access for those who live off campus. The use of the Real format also adds to the security of copyrighted material for on-campus use.

The video material consists of a general introduction to the laboratory course and to safety issues, and separate video for each of the 43 exercises listed in our laboratory manual[15]. Each exercise-specific video is incorporated into a single page on the WebCT server and consists of three parts:

- an introduction describing the background to or purpose of the exercise;
- laboratory procedures including chemicals, apparatus, safety considerations, and residue disposal;
- representative calculations.

The average video lasts six to eight minutes, may be viewed an unlimited number of times, and may be paused, rewound, and fast-forwarded. Undergraduate students act as presenters in the videos and visually walk students through the laboratory exercise showing techniques, apparatus and calculations. We chose to use undergraduate students to present the material on tape because we felt that students often listen to each other and understand what their peers are saying better than they do with academic staff even when the words are exactly the same. Our primary criteria for selecting presenters were their ability to read aloud well (clearly and distinctly) and their successful completion of the Introductory Chemistry course on our campus.

On the same page as the video is a pre-laboratory quiz. The quizzes are worth 10 percent of a given lab grade and can contain anywhere from three to ten questions. The question format is variable and may include short answer, discussion, single response multiple choice, multiple response multiple choice, matching, or calculations with randomly generated numerical values. The quizzes become available to students beginning one week prior to the scheduled laboratory period and are unavailable two hours prior to lab. Quizzes may be taken only once, but students choose whether to take the quiz simultaneously with or independently of viewing the video. They are 'open book' and 'open note.'

While the value of the quiz grade may seem low (10%), it appears to be enough to encourage students to take the quiz without cheating. The quiz grade is immediately available to the student and the lab TA. A student may also access any other grades the TA may have imported into the database. It is here that students may see class statistics and note their own ranking among their classmates.

A tool named 'Class Experiments' allows class data to be collected and distributed to each member of the section. A 'mail-form' is incorporated into pages within the Class Experiments path. For selected experiments students enter data as it is collected into the form in WebCT on a computer in the laboratory and this is then immediately e-mailed as a text file to the TA who checks the data, makes notes, and forwards the form on to each member of the section. The students then use data from the whole class in writing their own reports.

Results

TA Response

Viewing of the videos by the TAs is entirely voluntary. Nevertheless, all of them report that the videos provide a valuable way to prepare themselves for their teaching role. They particularly value the flexible access which allows them to study the videos at a time and place of their own choosing. They find the explanations and discussions are extremely helpful in enhancing their understanding of the terminology. As an example of the use of constructive use of videos by TAs, a group of four Chinese TA's informed the lab manager that they get together as a group, watch the video several times, discuss the language and techniques, and anticipate questions that their students might ask.

Student Response

Before we introduced the on-line pre-lab material, it used to take as much as 40 minutes of the three-hour lab session for the TA to provide information and before students could start their work at the laboratory bench. This time was spent finding out what lab they are doing, reading the procedures for the first time, asking questions of fellow students, gathering materials, etc. The introduction of the WebCT tools has greatly facilitated the flow of the laboratory exercise. TAs report that the 'time on task' is substantially higher and there are fewer questions regarding techniques and calculations.

The mark associated with the quizzes provides sufficient incentive for all the students to complete these. Since the questions are linked to the videos and the laboratory manuals, the quizzes encourage students to read their lab manuals and view the videos prior to lab. However, the quizzes are responsible for most of the negative responses regarding the use of WebCT. The problems centre around two main concerns:

- short answer questions where the student response must *exactly* match that in the program;
- calculating answers where students are not in the habit of concerning themselves with the proper use of significant figures.

They have very little trouble with matching, single- or multiple-response multiple choice, matching, or True/False questions.

Discussion

The technology needed to create this resource is neither prohibitively expensive nor is it difficult to use and can be made even more advantageous with institutional collaboration. If two or more colleges or universities are doing the same or very similar laboratory exercises, the videos could be non-institutional-specific. With the exception of an orientation video, much of the material produced on our campus may be transferable to others using the same laboratory manual. What is needed most, however, is a well-defined and carefully thought out script. Two persons worked on writing the scripts from a selected set of labs in our lab manual[15]. Each person wrote a script alone and then passed it along to the other for review. When the two were satisfied that the content was acceptable, a third person was brought in to read the script aloud. This ensured that what was envisioned in printed word sounded correct on tape.

The preparation of a script took 2-3 hours for each exercise-specific video, filming took another 2-3 hours, and editing took a further 4-5 hours (shorter now with Adobe™ 5.1RT software). This investment of time results in material which can be used each year (three terms per year if semesters and four terms per year for quarters) for as long as the particular lab manual it was scripted from remains in use – often 5 years or more. When one considers that a video which took 8 to 12 hours to produce is being used for at least 15 terms and with countless numbers of viewings, the time investment is very reasonable. In contrast to the computer-based pre-labs such as those described by Nicholls[8] and Tomlinson et al[17], this approach does not rely on the availability of a skilled computer programmer. All the equipment needed both to create and disseminate the video packages is simple enough to be operated by an academic with enthusiasm. The results may look less professional than the videos created using the substantial resources available to the Chemistry Video Consortium[10]. However, academic chemists from other departments have been impressed by the quality, and have agreed that the low-cost approach has not significantly reduced the value of the product.

A further advantage to this approach to pre-lab work is that it is extremely easy to edit and update each video. Should a procedure or apparatus in a particular experiment change, two options are available to accomplish the update:

- if the original undergraduate presenter is still available, the changed segment can be filmed again and the changes edited into the video; or
- if the original presenter is not available, the entire script can be filmed again, using the original graphics and data with a new presenter.

The approach described here does not depend critically on using WebCT, since other modes of delivery are available. These include Blackboard™[17] which has just acquired Madduck, Inc., and its product Course-in-a-Box; SocratEase™ by Eutectics Corporation[18]; convene.com; Educator® by Ucompass.com; ecollege.com; eWebUniversity.com; and e-education.com, to name a few.

We have found, however, that WebCT is easy to use, is password protected, is viewable with either Netscape™ or Internet Explorer™ browsers, is flexible in that it is easily edited and tools can be added or subtracted as needed, and is relatively inexpensive.

Conclusion

Experience indicates that anyone wishing to increase the quality of the learning experience from lab work would do well to consider the following points:

- providing a proper and safe laboratory environment;
- supplying a set of meaningful and well written experimental procedures;

- connecting the laboratory exercises to the Chemistry lectures;
- providing the students with information and assessment regarding lab in such a manner as to provide time to reflect prior to assigned laboratory time;
- provide a mechanism for questions and feedback in an unstructured environment;
- provide access to grades in a timely yet secure manner; and
- make the process of learning as timely and as meaningful as possible.

The institution provides the laboratory environment, the authors supply the experimental procedures, and the laboratory manager or laboratory instructor connects the lab to the lectures. The use of an on-line process for providing information, assessment, bulletin boards, chat rooms, and grade databases is critical in making the learning timely and meaningful. Students may spend as little or much time in preparation as they deem necessary, but they are encouraged to prepare and are provided with every mechanism to do so.

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