Teaching safety: 1000 students at a time

The safety training program for undergraduate lab students at the University of California, San Diego, Chemistry & Biochemistry Teaching Labs is based on self-study and gateway testing. Study materials are made available to the students, an optional safety lecture is provided and students are given venues to ask questions. Each lab student is required to pass an exam on basic lab safety and our specific laboratory rules. Our system for implementing this program and some of its problems are outlined.

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INTRODUCTION

As safety staff in the UCSD Department of Chemistry & Biochemistry, we first addressed using the web to teach Lab Safety to undergraduate lab students 10 years ago.1 We talked then about using our web pages as a medium for presenting lab safety topics to our undergraduate lab students. The present article addresses our training and testing program as it has functioned for ten years and our plans for the next step going forward.

Our current training and testing program begins with our Teaching Labs website2 which is embedded in our department Academic Program pages.3 The Teaching Labs website is the student's source for general information and staff contacts; our Laboratory Regulations4; access to the University’s material safety data sheet (MSDS) search engine; and explanations about how the training and testing program works.

SELF-STUDY PROGRAM

Our training program is based on student self-study and gateway testing. The department safety staff works with the course instructors and graduate teaching assistants (TAs) to make study materials available to the students and be available personally to students and TAs to answer their questions. Each student registered for our introductory lab courses chooses from among the materials presented and studies the topics presented. Each must then pass an exam on those topics. Figure 1 shows the flow of events as students work their way through the program.

Our student self-study training program differs from the our campus's new employee Lab Safety Training, which is presented by our campus EH&S Department. In a mandated new employee program, the EH&S Staff presents the required materials and the new employee is required to attend the presentation. As long as an employee shows up, signs in and stays through the presentation, attendance is equated with training; there is no testing component to assure comprehension. In our Teaching Labs program, the students are invited to attend our safety lecture and bring up any questions they have, but they are not required to attend or read any particular materials. The gateway for being retained in – or dropped from – a lab class is passing the safety exam.

An unfortunate consequence of gateway testing has been a strong focus, on the part of the students, on the examination rather than the training. In a way, that emphasis suits our students. We have a population of extremely result-oriented students; if a grade or points toward a grade is at issue, their attention is assured.

Many of our lab students have previous experience with our program, but a large group (~500) are new in each ten-week quarter. To assure that everything is clear, announcements are published about the program via various media. Figure 2 shows the announcement published each quarter in the University Schedule of Classes. The course syllabus for each of the introductory courses includes a statement about the training and testing program, usually with a link back to our web page. In addition, a summary page is printed as a poster and placed on the doors to all affected lab classrooms. The same page is published in the department web pages (see Figure 3).

LAB SAFETY RESOURCES

On the first day of class, the graduate teaching assistants (TAs) who teach the individual lab sections are
instructed to use part of their first three-hour laboratory meeting to introduce students to safety equipment. They are to instruct the students in the location and use of:

- Fume hoods
- Broken glass boxes
- Safety showers and eyewashes
- Small sharps containers
- Bottle carriers
- Fire extinguishers
- Fire blankets
- Bottle carriers

The Lab TA is also instructed to remind students of the available self-study resources for lab safety topics and the timelines for study and exams.

To begin the self-study portion of the safety training, students are referred to our Teaching Labs home page (see Figure 4) which shows links to:

- On-line documents:
  - Our Laboratory Rules
  - Our in-house STUDY GUIDE

- MSDSs
- Emergency response
- Building evacuation plans
- Hazardous materials storage
- Personal protection
- First aid for chemical spills

We have been known to tell horror stories, but dramatic lab accidents

**SCHEDULE OF CLASSES**

**ATTENDANCE AT THE FIRST LAB MEETING IS MANDATORY**

Check the class web site for first-day information and come to lab prepared to work. Students who miss the first thirty minutes of the first lab meeting of the quarter will be administratively dropped from the course.

**LABORATORY SAFETY REQUIREMENT**

All students in CHEM 6BL, 100A, 143A and 143AM are required to demonstrate an understanding of general lab safety and of the UCSD Undergraduate Chemistry Lab Rules. Passing the Lab Safety Exam (administered in the second or third lab meeting) fulfills this requirement; students who do not pass the Lab Safety Exam may be administratively dropped from the course with the grade of "W." Information on the Lab Safety Exam (including study resources and topics which may be covered) will be distributed in the first class lecture. Each student is responsible for learning the material. Information on general lab practices and our specific rules can be found on the web at: http://chem-courses.ucsd.edu/Uglabs/ and http://blink.ucsd.edu/Blink/External/Topics/How_To/0,1260,14110,00.html .

Figure 2. Text printed in UCSD Schedule of Classes each quarter.
have been difficult to relate to the experience of a young student.

For students who learn by reading and want to have a written resource, we publish the Undergraduate Laboratory Safety Exam STUDY GUIDE & PRACTICE QUESTIONS. The GUIDE has been updated several times over the years. By directing students to both general resources, such as SAFETY IN ACADEMIC CHEMISTRY LABORATORIES, and to our local rules, we hope to introduce them to both general lab safety principles and the idea that each institution

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Figure 3. Lab Safety Training Announcement, UCSD Chemistry & Biochemistry Teaching Labs.
(and work place) has its own specific rules.

We also introduce students (both on our web page and in our lecture) to the UCSD EH&S Department and direct them to the EH&S web page for general information and other safety topics, such as biosafety and radiation safety. It is important to introduce the students to the EH&S department and to connect them to a more general understanding of lab safety, as many of our lab students go on to work in laboratory settings during their years at the University. While we do not train in biosafety, radiation safety or any of the many other fields EH&S covers, students should be aware that training is available and required in each of these areas when they need it.

LAB SAFETY EXAM

For the past ten years, our gateway exam has been a 25-question multiple-choice exam. In recent years, each test has including a question that requires the student to read an MSDS and identify the hazard(s) of the material. Repeated revision and re-thinking has resulted in a core set of multiple-choice questions that cover our essential topics and can be printed in the limited space available. Student feedback over the years has helped us find our ambiguities and clarify our questions. Each test fits on two sides of one sheet, plus a sheet for an MSDS in very small type. Printing costs are charged to the class budgets.

The exam is normally provided to the lab TA, who administers the exam during a regularly scheduled lab period and returns the materials to the Safety Coordinator. Passing score on the exam is 75% and we typically see 90% or better passing in all classes; the portion passing is often higher (95% or better) in the classes aimed at chemistry majors (Analytical Chemistry Lab and transfer students in other upper division classes). Some instructors use the safety exam score as a quiz score in class, but that varies among the instructors. Since we do not record lecture attendance, we have not tracked effect of the lecture on exam scores, but most students do attend in their first lab class.

Depending on the quarter, we examine about 1000 students in three or four classes. We typically see:

- 500 students in General Chemistry (Introductory Inorganic) Lab
- 450 students in the introductory Organic Chemistry Lab and Honors Organic Chemistry Lab
- 80–100 students in introductory Analytical Chemistry Lab

We score the exam on a Scantron machine, which allows us to process 500 exams in a few hours. We report the scores, on a spreadsheet, to the course instructor. The instructor posts the scores and students access their scores (via individual log-in) on the class web site.

It is the explicitly stated responsibility of each student to check the class web site for the test score and make sure s/he passed. All questions about scores

Figure 4. UCSD Teaching Labs home page with links to self-study resources.
are referred to the instructor at this point. We do not show individual test forms to students, partly to discourage memorization of answers to multiple-choice questions and partly due to the limited staff time available for this program. In recent terms we have responded to student requests by posting students’ responses (with ID numbers) along with the answer key. With the limited staff time available, we have concentrated an answering students’ questions about the training materials and the guidelines we want them to learn, rather than reviewing a test they will never see again. Students requesting specific test answers are redirected and encouraged to rephrase their questions in terms of learning the safety information, rather than answering a test question. Sometimes, the exercise of rephrasing the question helps to identify the specific need or confusion a student feels.

Students who fail the first exam have a second chance: a different 25-question multiple choice exam with an 85% passing score. At one time, the second exam was a combination of short-answer, multiple-choice and matching questions, in an effort to better test students who do not test well on multiple-choice questions, in an effort to better test students who do not test well on multiple-choice questions, in an effort to better test students who do not test well on multiple-choice questions, in an effort to better test students who do not test well on multiple-choice questions. Grading that exam was a combination of short-answer and matching forms to students, partly to discourage memorization of answers to multiple-choice questions and partly due to the limited staff time available for this program. In recent terms we have responded to student requests by posting students’ responses (with ID numbers) along with the answer key. With the limited staff time available, we have concentrated an answering students’ questions about the training materials and the guidelines we want them to learn, rather than reviewing a test they will never see again. Students requesting specific test answers are redirected and encouraged to rephrase their questions in terms of learning the safety information, rather than answering a test question. Sometimes, the exercise of rephrasing the question helps to identify the specific need or confusion a student feels.

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Our compromise was to change the second exam to a multiple-choice test with comments. We encourage students to comment on the exam, the clarity of the questions, the efficacy of the training program, etc. We request comments on anything to do with the training and testing process. Comments cannot hurt a student’s score but, for students who are close to failing the second exam, the comments sometimes show an understanding that is not apparent on the multiple-choice exam. For others, the comments affirm our judgment that the student is not yet ready to proceed.

About three years ago, at the suggestion of one of the instructors, we started holding a review meeting the night before the second exam. Students who wish to attend have a chance to ask questions, review the study materials and clear up any confusion. Comparison of the review meeting sign-in sheets with scores shows that those who attend usually do well on the second exam.

A few still fail the second exam almost every quarter. Of the small number (fewer than 5% of enrolled students) who do not fulfill the safety exam requirement for a lab class, the largest group who fail are second language learners who do not yet handle the English language well enough to test well. Since the language level is similar to that of the instructions given in the texts and lab materials, we feel this indicates that these students are not ready to safely participate in a lab class. Another small group is those who are too arrogant to study or who assume the exam will be too easy to require any study (as judged by personal conversations). A small number every quarter just do not show up for the second exam; some do not check their scores because they are sure they passed (again, based on conversations with students over the years).

For the past several years we have had a program that looks like the flow chart in Figure 1. The group labeled Continue with Lab Class is the largest group by far: often, more than 90% pass the first exam and more than 90% of those who take the second exam also pass. A calendar view is a little simpler (Figure 5), but it is still a very full two weeks at the beginning of every ten-week quarter. In Summer Session, which is five weeks, everything is done twice as fast and we try to have it all done in the first week.

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Figure 5. Calendar view of training and testing process for three introductory chemistry laboratory classes during the first two weeks of the quarter. Lab classes meet twice each week. Upper division classes (introductory organic and analytical chemistry) are tested in the second lab meeting; general (introductory inorganic) chemistry is tested in the third lab meeting.
ADVANTAGES

Early emphasis on a culture of safety. Since we begin our safety training with our most inexperienced lab students, we hope to build their expectations about the way things are normally done in labs. We know they will be exposed to other standards (both in other departments and in employment situations), but we get a chance to push our agenda early. Anecdotal reports from recent graduates of our program indicate that employers respond positively to an overt awareness of lab safety.

Reinforcement for graduate Teaching Assistants. Our graduate students arrive on campus from many other institutions and with a wide variety of training backgrounds. Participating in our training program and enforcing our lab rules with their students helps them to become part of our system and reinforces a culture of safety that may be new to them.

PROBLEMS

Resources. One of the problems with our training method is that it is resource intensive: the department safety staff spends an enormous amount of time testing and consequently less time teaching or otherwise interacting with students. Printing and recycling costs have risen, as have charges to the department for large lecture spaces outside our normal class schedules.

Waitlists. Another problem is that we are not serving as many students as we might. After dealing with two exams (typically in the second lab meeting and early in the second week of classes), we nearly always have some students to drop from the classes. Those few students who do not pass are dropped after the deadline to add a lab class has passed (at the end of the first week), while other students remain on the wait lists.

FUTURE DEVELOPMENTS

We are now in the middle of what is turning out to be a nearly two-year project to revamp the program. We have moved the exam from a paper test to an on-line exam, using the WebCT course management software.

In Summer 2009, the on-line exam was pilot tested with a small class (20 students) in a controlled environment (our computer lab). We found a few problems, as staff learned to work in the web environment. In the small class, unexpected results could be resolved quickly. A paper test was ready at hand, in case of complete failure. In a subsequent term, we expanded to two classes of approximately 80 students each, using the computer lab and testing one section (20–24 students) at a time.

As we meet here in San Francisco in March 2010, we are anticipating the start of Spring quarter next week. Then we will be releasing the on-line test for all three classes, about 1000 students. Since there is no testing facility on campus to accommodate large numbers of students at computers at one time, the students will be instructed to take the exam during a specific time period and results will be available to the Instructors as soon as the exam availability period closes.

In the coming terms, we hope to move the testing time frame back from the first week of class. We hope to place the gateway test before – or concurrent with – registration for the class, to attack the problem of spaces left open when students are dropped. We are consulting with our Registrar and the web development support staff on how best to tackle this.

Pushing back the testing time leaves us the problem of when to train our prospective students. We hope to work with the curriculum committees to insert a unit on lab safety into our General Chemistry lecture. The proposal is written and in review.

REFERENCES

2. The University of California, San Diego, Chemistry & Biochemistry Teaching Labs web site can be accessed at: http://www-chem.ucsd.edu/academic/courses_labs.cfm.
3. The Academic Program pages for the University of California, San Diego, Chemistry & Biochemistry Department can be found at: http://www-chem.ucsd.edu/academic/academic.cfm.
5. The University of California, San Diego, Environment, Health & Safety Department web pages are available at: http://blink.ucsd.edu/Blink/External/Topics/Policy/0,1162,15498,00.html.
6. Undergraduate Laboratory Safety Exam STUDY GUIDE & PRACTICE QUESTIONS is available at: http://www-chem.ucsd.edu/academic/Instruc/lab/STUDY_GUIDE.pdf.