2006-201: TEACHING LABS: THE CHALLENGES AND PRACTICAL CONSIDERATIONS FOR NEW FACULTY

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Teaching Labs: The Challenges and Practical Considerations for New Faculty

Introduction

It is very common for untenured engineering faculty to be assigned the responsibility for teaching and managing a teaching laboratory in their program. At undergraduate institutions this is due to the relatively low numbers of faculty in departments, the faculty replacement process, and the desire for the program to update their laboratories. Similar reasons exist at graduate/research intuitions, but, in addition, we might add the unwillingness of senior faculty to carry out this task as a reason for the assignment of a new faculty member to this task. The purpose of this paper is to provide some guidance to new engineering educators who find themselves with this laboratory assignment. For the purposes of this paper, the term teaching laboratory applies to laboratories in which the students conduct physical experiments and not computer or virtual experiments. The two authors provide two different perspectives, one based upon the experiences at an undergraduate teaching institution and the second from experiences at a graduate/research institution. However, both of their experiences are within the thermal/fluids discipline of mechanical engineering. Some of the issues raised in this paper cut across the various engineering disciplines, but some may be more applicable to mechanical engineering or the thermal/fluids aspects of chemical or civil engineering than to other fields.

There are several good resources available to guide in the teaching of labs. The authors especially like the booklet put out by the Teaching for Learning Center of Flinders University, Australia[1]. It addresses goals, organization, and strategies for teaching labs and also provides details on occupational health and safety issues for teaching labs. A condensed guide for lab instruction can be found at the Center for Teaching, Vanderbilt University web site[2]. There are also some guides available for teaching assistants who are teaching labs. Two very good ones are [3] and [4].

The paper begins by considering the upkeep and maintenance of the laboratory facility. Next the staffing issues are addressed. The handling of reports and laboratory grading is then considered. This is followed by a discussion on the development of experiments. The paper concludes with a guide on handling laboratory disasters.

Laboratory Maintenance and Upkeep

The two principal resources required to maintain a laboratory facility are money and technician time. Typically, these are in short supply. Some institutions impose a laboratory fee to generate funds for laboratory maintenance. These monies may also be used to partially fund the salary of a technician. For institutions that do not impose such a fee, lab funds and technician salary will come from either general funds, endowments, or directed gifts. Regardless of the source of funds, they are often not readily available to the lab instructor, but controlled by the department head or chairperson. Hence, it is essential that the lab instructor negotiates with the department chair for these resources. The timing of these negotiations is critical for success. The best time to conduct these negotiations would be prior to accepting the assignment. That is, we strongly encourage the new faculty member to get a commitment of financial and technician resources for a laboratory course up front. At an undergraduate institution, the faculty member will strongly depend on the technician for laboratory preparation, upkeep and maintenance. Having a good working relationship with the technician will be extremely important for successful operation of the lab. New engineering educators need to be aware that this relationship can have unique challenges due to cultural differences that include, but are not limited to, age and gender. It has been the authors' experience at various universities and in industry that forming a positive relationship with a technician usually requires a 'get acquainted period' where each feels the need to prove their knowledge and expertise. Mutual respect will go a long way to fostering a positive working relationship. Unfortunately, if either party is reluctant to accept the authority or expertise of the other, the relationship can be very cantankerous in nature and ultimately detrimental to the smooth operation of the lab.

With respect to amounts, it is the authors' experience that $1000-$2000 a year for lab maintenance and supplies is sufficient. Certainly, this quantity will vary according to the nature and discipline of the lab and comes from the authors' experiences with mechanical engineering labs. This quantity will provide funds to purchase consumable supplies as well as some small equipment. Any major equipment purchases will need to be funded in some other way. As far as technician time, approximately four hours a week during the semester in which the course is taught will be needed. This time can be used for experimental setup and some minor repairs. Additionally, two weeks are typically needed when the course is not being taught (say, during the summer or between semesters) for more thorough maintenance. The new faculty member is encouraged to develop a lab plan for their facility, similar to what ABET requires for the program's laboratories. This plan should include a maintenance budget and schedule, a budget and schedule for equipment replacement, staffing needs, safety rules and enforcement, space requirements and specifications, and sources of funding.

Staffing the Laboratory

At undergraduate institutions, lab sessions are staffed by the instructor of the course who may be responsible for up to three other courses during the given semester. This requires a considerable commitment of time, but allows for significant interaction with the students. To enhance the learning process the students themselves may assist in teaching the lab. This requires that the class be broken up into groups and assigned an experiment that they are in charge of for the semester. Depending on the number of experiments and students in the course, this may require each group to lead 2 or 3 experiments. Each week the instructor will schedule a meeting with the lead group to walk through the experiment and assist in the preparation of the pre-lab lecture and data sheets. On the day of the lab, the lead group will give the pre-lab lecture, which includes an overview of the experiment, pertinent background information and needed data. They then lead the actual operation of the experiment. The instructor is present at all times to avoid any misrepresentation of information and to supervise the students as they conduct the experiment. This also allows for active learning by the students, as they are required to present to the class and answer questions. At the beginning of the next laboratory session a post-lab presentation is done discussing the results. A laboratory write up is required of all students for each experiment. A suggestion to provide some relief to the faculty member is to hire a senior-level student to assist in the lab; however, if the laboratory is a senior level course this option is not practical.

At research institutions, graduate assistants are used to staff the laboratory sections as teaching assistants. In this situation the faculty member's role goes from teaching the students to teaching the teaching assistants. Weekly meetings for the instructional staff are essential. It is suggested that the faculty member puts together and distributes a formal agenda as shown in Figure 1. The authors also suggest that the faculty member periodically visits the lab sessions, making a point to visit each section at least once every two weeks. This allows the faculty member to observe the teaching assistants in action and provides an opportunity to evaluate the TA, often required by the graduate teaching assistant unions now prevalent on campus.

Report Requirements and Grading

There are several ways to have the students report the results of their experiments. Three approaches that the authors have experience with are: formal reports, technical memos, and worksheets. In the formal report the student provides a comprehensive statement on the experiment, including its theoretical background, a thorough description of the apparatus and experimental procedure, experimental results, discussion, and conclusion. It is rather lengthy, 20-40 pages. A good formal report should demonstrate a very deep understanding about the experiment. It can provide an in depth writing experience for the students and can provide them with the opportunity to take a complex description and express it in their own words. Unfortunately, students often spend more time on the background, apparatus, and procedure than on presenting experimental results and discussing them. The authors prefer the technical memo approach, in which the students provide a brief description about the experiment and cut right to the chase on the results and discussion. We believe that this approach emulates what the practicing engineer would produce. The worksheet approach focuses solely on the results with directed questions to get at the desired discussion. The use of a worksheet can lighten the load for a very challenging lab course. The decision as to which reporting tool to use will depend on the learning objectives of the lab.

Grading lab reports can be a very laborious task, especially when an objective of any good laboratory is to emphasize technical writing. One technique that can make it a little more effective is the use of a grading sheet, an example of which is shown in Fig. 2. At research institutions, consistency in grading amongst the graduate teaching assistants becomes an issue. We have found that by using such a grading sheet and briefing the teaching assistants, quite often leads to consistency in the grading of the reports. At an undergraduate institution, the shear number of reports to be graded on a weekly basis can be daunting. One approach to reduce the number is to require some group reports. The benefit to the students is to encourage collaboration in writing and editing such that each report, independent of format, reads with one blended voice.

Figure 1 Lab Staff Meeting Agenda

ME 412
Heat Transfer Laboratory

TA Meeting 3/10/03

<u>Agenda</u>

1. Lab Problems or issues

2. Attendance: Heat Exchanger – NONE, Conduction - NONE

3. Conduction Experiment
   a. Review

4. Heat Exchanger Experiment
   a. Review

5. Radiation Experiment
   a. Lecture
   b. Proposal and Scheduling
   c. Reporting
   d. Grading

6. Power Plant Simulation
   a. Lecture
   b. Rankine Program
   c. Grading

7. Power Plant Tour
   a. Schedule

8. Other Business

Figure 2 Lab Report Grading Sheet

ME 412
Heat Transfer Laboratory
Forced Convection Over a Cylinder Experiment
TA Grading Sheet

Basic Grade _______ Graph of Nu vs Re with curves of two experimental data sets (different diameter cylinders) and two "theoretical" correlations. -40 _______ Sample calculation of h_c, u_f, Nu, and Re. -10 _______ Error bars in both directions for data of Nu vs Re. -20	/70
Discussion General Discussion on the comparison of experimental Nu's with correlation Nu's, including consideration to uncertainty error. ±10 There is probably not a geometric dependence, but is would show up if the two experimental data sets do not collapse to one curve on Nu vs Re. ±5 The cylinder voltage drop varies with velocity, because the electrical resistance of the cylinder varies with surface temperature which varies with velocity. ±2 Some possible systematic errors might include, natural convection effects, free stream turbulence, wind tunnel side wall affects (not truly an external flow), radiation effects. ±3	/±20
Memo, Data, & Graph Quality -8 → Very poor 0 → Mediocre +8 → Outstanding	/±8
Above & Beyond _______ Library work _______ Additional discussion _______ Additional insight	/2
Total	/100

Revising or Developing Experiments

In revising old experiments or developing new experiments, it is important to set objectives. Clear objectives are needed in order to develop a laboratory experience that enhances student learning. Typically, the learning objectives of an experiment are as follows:

1. Teach the use of instrumentation and apparatus that are unique and/or special to the discipline of interest.

2. Demonstrate the fundamental aspects of the discipline.

3. Employ experimental principles and thought processes to solve engineering problems.

Ideas for revisions or new experiments can come from the faculty members own experiences, student feedback, the engineering education literature, or visits to other institutions. There are several companies that manufacture experiments for engineering teaching labs. Most of these are plug and play, but one can expect to spend between $25,000 and $50,000 for such an apparatus. A cheaper alternative is to build the apparatus on site. This requires the availability of a skilled technician. It has been the authors' experience that such an on site fabrication will require considerable faculty time and effort devoted to the design and build, as well as the thorough testing of the apparatus before it is set upon the students.

Handling Laboratory Disasters

It is a fact that equipment breaks and that even the most careful student may have an accident. To minimize these situations, experiments need to be designed to be rather robust. When possible, backups to key equipment should be available. Safety rules need to be distributed to the students and the students should be asked to sign a form stating that they have read and understood the safety rules of the lab. The lab staff needs to reinforce good and safe laboratory practices as they supervise the students conducting experiments. Even with these preparations, bad things happen in the laboratory.

When an experiment breaks down and cannot be repaired during the lab session, there are three options available to the instructor. The first is to simply forget about the experiment. The second is to reschedule the experiment following its repair. This alternative is not very acceptable to the students and may be logistically impossible for programs with large enrollments. The third option is to provide the students with data collected previously and, at the least, give them the opportunity to process the data and write their reports. In order to implement option three, there must be previous data available. The authors strongly encourage laboratory faculty to maintain a benchmark set of data for each experiment in the lab. In addition to the break down problem, this data can be used to confirm that the students are actually conducting the experiment and conducting it properly. It may also serve to alert the instructor to possible equipment failures.

In handling accidents that lead to physical harm of a student, it is very important that there is a plan in place to handle these situations. This plan might include administering simple first aid to calling an emergency medical team. The laboratory faculty must develop such a plan and train the lab staff in its implementation.

Conclusions

The views presented here are based on a combined 30 years of experience with teaching undergraduate laboratories. The authors have always found the experience to be very rewarding but also very labor intensive. Fortunately, the authors thrive on the challenges found in undergraduate teaching at both types of institutions.

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