Lighting the Fire

The advanced laboratory experience plays a pivotal role in undergraduate physics, yet it is often taught in isolation. A former AAPT president explains why it's crucial to bring the advanced physics lab in from the cold.

BY DICK PETERSON

dvanced physics laboratories (typically junior or senior level—atomic and nuclear, condensed matter, optics, fluids or acoustics) have a long tradition in colleges and universities, yet they often have different goals and curricular structures at different institutions. Sometimes advanced lab experiences are incorporated within distinct upper-division courses—such as optics, electronics, atomic or nuclear physics—while other departments have a more traditional, stand-alone "advanced lab" that seeks to effectively bring together several areas of physics and their respective experimental techniques.

The departmental structure of such labs has often resulted from heroic works of the past in a department, and yet it is still true that a young experimentalist may be assigned to cover such a lab, and—after looking over a chaotic assemblage of dusty equipment—decides on a survival strategy for the short term that also builds on his or her particular background and interests. Still, whether in a college or large university, such a "can do" individual will likely develop his or her own approach, given that department's resources, and often observes that the learning and maturing experiences of impacted students are some of the most influential of their undergraduate years. But these diverse advanced lab challenges are often experienced in relative isolation from other workers, and, even in large departments, colleagues may have limited experience with essential lab equipment or access to helpful pedagogical insights or even share an underlying commitment to the cause. Accordingly, the Advanced Laboratory Task Force (see Sidebar, page 18) has presented several recommendations aimed at bringing advanced lab instructors together for mutual assistance and to sharing ideas and experiences.

It's All About Students

"Education is not the filling of a pail, but the lighting of a fire," wrote W. B. Yeats. The advanced lab instructor, whether in a stand-alone course or as the lab component of another upper-division course, is invariably looking for creative student experiences that both affirm and light a fire. Yet even at the junior and senior level, an experiment that yields an illuminating "eureka" moment for one student can be a "burn-out" for another. So the advanced lab instructor must orchestrate varying student strengths and interests, build on lab group dynamics, and always be on the lookout for a positive "ignition" event. Combining this creative investigative quest with the pressures for a broad experimental exposure, building lab computer and data analysis skills, along with polishing written and oral communication skills,





leads to the daunting, yet rewarding, role of the advanced lab instructor. These many pressures have motivated some departments to strategically spread advanced lab experiences over several instructors and courses.

For example, besides extensive sophomore-level experiences in electronics and atomic/nuclear labs, the Bethel University physics and applied physics B.S. programs emphasize significant advanced lab experiences within optics, laser physics, fluid mechanics, and computer methods classes. Advanced labs (in classes averaging about 15 students) often start with five to six or more weeks of constrained and guided exercises, followed by six to seven weeks of open-ended projects. The larger projects conclude with LaTeX journal-quality written reports and group oral presentations.

What are the biggest challenges and payoffs from a major emphasis on advanced labs? In many upper-division classes, associated labs may require at least as much time as lectures during portions of the semester, and this must be reflected in teaching loads. In my experience teaching optics or laser physics classes in this mode, lecture and lab often combine to nearly a full-time job. In addition, while clever and challenging advanced lab projects can be built around modest equipment, it is still clear that



Chad Hoyt (center) works with students Gus Olson (left) and Sarah Anderson in achieving rotational line tuning of a frequency stabilized, sealed-off CO₂ laser.

state-of-the-art physics at this level can often profit from good quality and rather costly equipment items. The major benefactors of these investments in staff and apparatus must be students; yet, when successful, these programs can impact the morale and visibility of an entire department, especially in the case of smaller undergraduate institutions.

PUTTING ADVANCED LABS ON THE FRONT BURNER

AAPT has long been identified with encouraging effective teaching of advanced undergraduate physics courses, in general, and advanced laboratory, in particular. In fact, the quest for community among and recognition of physics educators who devoted their energies to the advanced labs was a raison d'être for the association's founding over 75 years ago. For nearly half a century the AAPT Committee on Apparatus has sponsored a competition to recognize creative, innovative approaches to advanced laboratories.

Acting at the urging of Jonathan Reichert (TeachSpin, Inc.) and AAPT President Harvey Leff (Calif. State Polytechnic Univ.), AAPT founded a task force comprising eight of its members to assess how AAPT could encourage collegiality among advanced labs practitioners as well as bring visibility to their distinct challenges and notable accomplishments within the larger physics education community. The Advanced Laboratory Task Force (ALTF) was formed in late 2005, and it issued its final report in July 2006 (www.aapt.org/aboutaapt/AdvLabTaskForceReport.cfm). Among ALTF's recommendations, several are highlighted below:

- 1. AAPT should establish the tradition of predictable advanced lab sessions, tutorials, and workshops at national meetings.
- 2. Toward raising the visibility of AAPT's commitment to the advanced laboratory, an initiating special conference should be held on common issues faced in the teaching of advanced laboratories.
- 3. AAPT should establish an award to recognize significant accomplishments in advanced laboratory development and instruction.
- 4. AAPT should demonstrate its leadership in improving advanced laboratory instruction by developing the premier website for advanced laboratory course materials and "tricks of the trade." The website should also serve to maintain communication within the community of advanced laboratory instructors.

AAPT has established a listserv at www.aapt.org/advlabs.

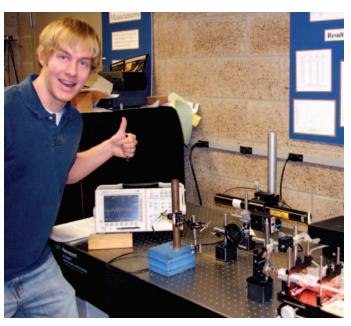
The goal of the listserv is to foster a continuing conversation on topics related to advanced labs, ranging from equipment purchases to experimental procedures. Also, as part of the ComPADRE project, AAPT will soon launch a website to provide information and other resources on advanced lab materials. Stay tuned at www.compadre.org.

What do students remember from advanced labs? Most likely they first recall the humorous events or goof-ups. Perhaps more than one reader will never forget that sinking feeling seeing that open, full box of holographic plates—after a few minutes of room lights. I remember one embarrassed Zeeman effect group (and this instructor) the next day with puffy, red eyes after ignoring the UV from the unshielded Hg lamp! However, following from the pedagogical goals summarized above, some students will also recall real gain in self-confidence or professional direction during advanced lab experiences. Almost every advanced lab instructor can tell of students who, having been "brought low" by a plethora of differential equations or Feynman diagrams, were able to find some redemption and confidence from a lab experience where they could really build something, make it work, and measure some physics—and they went on to great careers. Other times they also see the lab experience contributing to their resume for that great summer job or NSF-REU. LabVIEW, MATLAB and LaTeX experiences are expanded, and they may be better guided toward professional careers befitting their special aptitudes and interests.

Some Big Questions

What larger issues loom that many see as foundational to advanced lab instruction in the 21st century? There are many, and they result from growing knowledge of effective pedagogy for today's students, upper-division curricular responses to changing student needs and career paths, impacts of new technologies on lab procedures and analysis, and changing sources of funding for advanced labs. Clearly the agenda for debate and presentations at an opening conference on advanced labs would not be wanting for pressing issues, including the following:

- 1. Does the traditional advanced laboratory based on a semester or two of foundational experiments make sense today? If so, how can these experiments best build on student creativity and flexibility while still conveying the historical roots of the original work?
- 2. Interactions of advanced labs with undergraduate research programs and preparation for quality NSF-REU experiences are increasingly important. To accomplish this end, some departments are strategically spreading advanced laboratory experiences (including analytical and computational skills) over two or three undergraduate years—often in a project mode that is well integrated into several undergraduate physics classes.
- 3. While advanced labs clearly depend on good equipment that works well and reliably, it remains important to also pass on the spirit of "making from scratch" and to nurture the troubleshooting experience. How does one best achieve



Bethel University student Chris Scheevel celebrates his successful alignment of a helium-neon laser.

- this needed balance? Many current students lack the craft and construction skills assumed in the past, while adaptive computer skills (including interfacing of instruments) are strong and acquired quickly.
- 4. As students increasingly prepare for varied careers, pedagogical goals of advanced labs should reflect these broader perspectives. Student writing and oral presentation skills grow in importance, especially as they may relate to communicating with a broader audience. Applied physics, engineering physics, and other interdisciplinary perspectives increasingly broaden the undergraduate curriculum. Advanced laboratory work in areas such as applied optics, metrology, fluids, acoustics, and nuclear engineering is increasingly needed, and industrial support of advanced laboratory and undergraduate research facilities can play a role in an era of limited NSF support for physics education.

In a sense we see that advanced laboratories represent a microcosm of the many pressures on physics education today. Nevertheless the physics education community simply must rise to meet the challenges of these varied experiences at a critical juncture of the undergraduate years. Δ

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