

2001 ACADEMIC-INDUSTRIAL WORKSHOP

Sunday, October 21, 2001

The Academic-Industrial Workshop, held on Sunday, October 21, 2001, is the second in a series intended to stimulate dialogue between industrial and academic leaders on subjects of mutual importance to them and to the physics community. The workshop is held in conjunction with the Industrial Physics Forum in order to increase this vital interaction.

This year's workshop focused on the articulation of the central role that physics departments play in creating the community of physicists, and in influencing the broader public with regard to its attitudes about science and scientists. Central to this theme is the principle that a physics department and its program of study should be shaped and influenced by the future employers of its graduates, and should be responsive to the needs of its students and their future employers.

To that end, the workshop's agenda was divided into three thematic sessions. The first focused on revitalizing undergraduate physics programs, offering a rationale for why such revitalization is necessary and two examples of successfully reformed programs. The second featured successful implementation of special projects funded by the National Science Foundation, since programmatic change must often be supported beyond the ordinary. And the third dealt with the concept of industry-university research partnerships, intended as an introduction to a future workshop slated for 2002 in Williamsburg, VA. Each session was comprised of short narrative presentations, followed by a brief panel discussion and breakout discussion period by the participants. Considered by many workshop organizers and participants alike to be the most important element of the day, the breakout groups reported the results of their discussions at the end of the day.

“Spin-Up”: Constructive Departmental Responses

Recent statistical information indicates that undergraduate physics education in the U.S. is in trouble, according to keynote speaker Robert C. Hilborn, a professor of physics at Amherst College and chair of the National Task Force on Undergraduate Physics. Only 25% of high school students take physics, although between 70-75% go onto two or four-year colleges and universities. About 350,000 college students take introductory physics, 35% of those at two-year community colleges. However, only 3% of students who take a calculus-based physics course ever take another course in the subject. As a result, there is a corresponding decrease in the fraction of bachelor's degrees nation-wide awarded in physics. “There is a new environment for physics education, with a changing national focus on K-12 education reform,” said Hilborn. “There is also a changing student population, and a changing role for physics in the universe of science. The revitalization of undergraduate physics is a constructive and creative response to this changing environment.”

However, while the number of undergraduate physics majors as a whole is declining steadily each year, certain individual departments are actually thriving and growing. The Task Force has developed Strategic Programs for Innovation in Undergraduate Physics (SPIN-UP), funded by the Exxon-Mobil Foundation. SPIN-UP's focus in the coming year will be on completion of site

visits to about 20 departments with thriving undergraduate physics programs, and of a corresponding survey of all physics departments. A case study report compiling the findings of the site visits will be distributed to all physics departments in the country.

SPIN-UP is based on three guiding principles. First, it recognizes that revitalization is more than mere curriculum reform, and hence it does not focus solely on that aspect. Rather, the program emphasizes departmental interactions with students in class, in the research lab, and in advising and mentoring. Second, the department is the critical unit of change in undergraduate education, although it relies on individual faculty members to carry out its activities. Finally, all reform is ultimately local, and the same model will not work for every single physics department. When it comes to revitalizing physics departments, one size doesn't necessarily fit all. "There are many ways to apply the principles of successful programs to the local situation," said Hilborn. "Each department must identify both its local mission and the resources needed to carry out that mission."

For example, when the physics department at the University of Illinois, Urbana-Champaign, began revamping its curriculum in 1996, it faced a challenge common to many large state universities: huge classes for introductory physics (about 2500 students each semester) placed a heavy burden on the faculty member assigned to teach them, and burnout was a common problem. The lectures were augmented with small discussion sections by TAs, and labs that were intellectually disconnected from the rest of the course. Exams were solely comprised of quantitative problems. The department chose to implement a "team teaching" environment, according to faculty member Gary Gladding, in which the burden is evenly distributed among several faculty members. The result: "No heroes, and no burnout, because both the pain and gain are shared," said Gladding. "We sought to integrate all aspects of a physics course using active learning methods based on physics education research in a team-teaching environment."

The new program emphasizes concepts rather than just calculations -- the same problem that had an average student score of 55% in the traditional quantitative exam achieved a 91% average score when presented in conceptual format -- and it employs active learning methods, because learning physics is not a spectator sport. "Actively engaging the students in a collaborative learning process promotes mastery of physical concepts through manipulation of experimental apparatus," Gladding contends. The new curriculum, instituted in the spring of 2000, also employs what Gladding terms "Just in Time" teaching, in which students complete a short quiz prior to class to give the instructor a sense of how well they grasp a given topic. The instructor can then adapt classes to the specific needs of the students.

Web-based homework assignments using interactive examples are another successful innovation at UIUC. Described as Web-based "Socratic dialogues" designed to develop concept-based problem solving, an interactive example consists of a quantitative problem as a base question, and it is a multi-step process, providing questions for which more help is always available. Immediate feedback is given, and questions must be answered correctly to receive additional assistance to eventually solve the problem.

Ironically, existing faculty are often the main obstacle to exporting the UIUC model to other

institutions, since they tend to resist change. “Organizational change is almost an unnatural act for physics departments,” said Gladding, “Yet it is probably more important than any of the substantive details I’ve described.”

The Colorado School of Mines has a very different situation, and hence a very different model for success. It is a much smaller school than UIUC, with a technology-focused mission in the areas of energy and materials research, and hence most of its students are already predisposed to science and engineering pursuits. Despite its small size, CSM is among the top 20 colleges and universities nationwide in terms of producing physics majors, and its recruitment is up 20% in the last five years: 27 BS degrees in physics were awarded in 2000. James McNeil, a professor in the physics department, attributes this to the fact that every student is required to take Physics I and II. These courses are taught by the best teachers, because this presents a prime recruiting opportunity to draw students into the physics department. The college administration values teaching, tends to hire student-centered faculty, and encourages and rewards teaching innovations, believing that having faculty involved in education reform is invaluable to recruitment and retention. There is good alignment between the missions of the DOP and the institution as a whole.

Because of CSM’s close proximity to high-tech industry and national labs, the curriculum has an applied emphasis with flexibility for alternate career paths built into it. CSM also has an active learning aspect to its curriculum. The department’s lecture hall has white boards on its walls so if students need to work a problem during lectures they can get up and do so. The department also tries to foster a strong sense of community. Every physics major gets a key to the building, and because of the close layout of the classrooms and offices, there are lots of chance hallway encounters between faculty and students, even a student penthouse lounge.

CSM has strong ties with local industry -- it receives \$24 million a year in sponsored research funding -- and hence considerable focus is given in the curriculum to preparing its graduates for science-based careers. For example, physics students are required to participate in one summer field session, a six-week hands-on internship to provide practical skills training in a diverse range of fields, including machining, electronic interfacing, and vacuum and thin film technology. Roughly half the physics students also opt for a special five-year combined bachelor’s and master’s program, specializing in materials science, for example, and seniors can design their theses to be aligned with individual research interests. This is possible because the physics department is strongly allied with the engineering department. “This kind of strategic alliance is the key to our success,” said McNeil.

Departmental Adaptation and Implementation

Introductory physics courses are not the only curricula in need of reform. Corinne Manogue of Oregon State University described her institution’s efforts to revitalize its upper division curriculum by adopting an organizational approach built on fundamental paradigms in physics. “We need to change the pedagogical structure to one of collaborative learning for juniors and seniors,” said Manogue, and that includes content, scheduling, pedagogy, and the so-called hidden curriculum, which she described as “all the things faculty do to help students become better than

is not part of the official curriculum, such as teaching them how to write and communicate better.”

OSU’s old curriculum had long course sequences, with rigid scheduling, and traditional subdisciplines. And with its students overwhelmingly industry-bound, it was felt that modern topics were needed that reflected many interdisciplinary interests. The revised curriculum is built around nine case studies of paradigmatic physical situations, using conceptual examples and spanning two or more subdisciplines, such as energy and entropy; spin and quantitative measurement; central forces; 1-D waves; and periodic systems. It covers a quantum and classical base and strives to develop problem-solving skills in students through its employment of modern pedagogical strategies.

According to Manogue, the primary advantage of this approach is its smaller pieces, which gives the program more flexibility. There are also closely integrated laboratories. In the senior year there are traditional first quarter lectures, single deductive subdisciplines, and specialty courses tailored to the strength of departments, which gives students more of a choice as to what they wish to focus on in their studies. Both collaborative and independent learning are encouraged with student-centered activities, including small group activities, integrated laboratories; learning cycles; projects; journal research; and visualization tools.

However, active engagement, while effective, is a slow process. OSU is in the process of compiling profiles to demonstrate the revamped program’s success. Based on initial feedback, some early problems with the revised curriculum include too much work for both students and faculty; no texts; occasional ego conflicts; and the lack of an exam rehash. Also, some students didn’t like the smaller groups and laboratories. The program’s early successes include strong student camaraderie and faculty enthusiasm. “The learning is different, but not less, and students like the focus and find the cross-disciplines motivating,” said Manogue. “In fact, some at risk students have blossomed under the new curriculum.” OSU’s current focus is on institutionalization: defining what has been accomplished thus far and preparing materials so that future teachers can carry on the changes that have been made to the curriculum.

An important emerging element in education reform is the development of digital libraries. According to Cathy Manduka of Carlton College, who spearheaded development of a digital library for earth systems education, digital libraries provide new tools and new opportunities in a changing educational landscape. There is a new emphasis on lifelong learning in our society, along with a shifting economic and national agenda, and a changing relationship with both industry and government. There is also new research on the learning process itself, while at the same time, technology is changing the way things are done in the classroom. In such an environment, educational digital libraries provide a Web-based compendium of available learning resources, including data access for inquiry-based activities, people networks, and supporting services for effective creation and use. “It’s a new way of doing business,” Manduka declared. “The result is a broad sharing of renewable learning resources, data aggregation sharing for science and education, and specialized communication networks.”

Electronic information is being created in many formats, stored in many repositories around the

world, and becoming increasingly interconnected via electronic networks. Digital libraries research is faced with the challenge of applying increasing computational capacity and network bandwidth to manage and improve accessibility to these large amounts of complex data, transforming it into information and knowledge. Innovative research and applications are being jointly supported by the National Science Foundation (NSF), the Defense Advanced Research Projects Agency, the National Aeronautics and Space Administration, and others. Since the original initiative was first introduced, technologies have advanced; stores of digital content have increased dramatically; and new research directions have emerged, all pointing to a future in which vast amounts of digital information will be easily accessible to large segments of the world's population.

Steep declines in the prices of commodity components over the past decade combined with availability of high bandwidth access have made sophisticated information technology applications affordable for many educational organizations. State of the art digital and internet-based services combined with rapidly expanding global digital content of all forms are now available for emerging applications in undergraduate education. The learning experience is being transformed by information and communications technology and the Internet in particular. Students increasingly turn to the web for educational and scholarly material, and there is a corresponding need for better integration of the different technologies and applications being developed in the learning and teaching processes, including digital library resources.

However, David Mogk of Montana State University pointed out that physics is noticeably absent from the NSF's efforts in this area. "Digital libraries can provide personalized learning, providing multiple pathways to the same educational goal, while forming extended networks with peers, mentors, and experts," he said. "Digital libraries link content with opportunities." Given the central role of physics departments as the interface between students and the real world, he believes this deficiency will only be addressed if the departments themselves champion the cause and push for adoption of digital libraries and other innovative educational tools.

Industry-University Research Partnerships

There is also an urgent need to promote research partnerships between industry and universities, according to Ralph Cavin, vice president of research operations at Semiconductor Research Corporation (SRC). He described his organization's model for encouraging such interaction, with the ultimate goal being increased competitiveness for industry. Approximately 87% of SRC's funds go to research, in the hope that "Eventually SRC-driven research will achieve a critical mass and become a dominant force in industrial research and development," said Cavin. This is particularly vital in the semiconductor industry, which expects to reach the limits of existing bulk CMOS technology after 2015 -- thanks to inherent limitations of lithography, device performance and interconnect scaling, and power dissipation, among other challenges -- and is in need of radically new technologies on which to base the microelectronics of the future.

Cavin summarized a few key lessons he has learned during his tenure at SRC. "The corporate model functions best as a partnership between university and industry," he said, but strong and continuing interaction requires an understanding of the very different cultures and values of the two arenas. For

instance, industry requires a value model for research, and usually expects “deliverables” on a timely basis, whereas universities may have a more curiosity-driven approach to basic research, with less emphasis on eventual real-world application. To help bridge this gap, Cavin suggested that universities should strive to involve industry personnel in some capacity in their research, to help identify areas that might prove valuable to that sector. “Pay attention to technology transfer, because it’s vital,” he cautioned. “Collaborative pre-competitive research can be a winning strategy.”

The final speaker, Charles Duke of Xerox’s Wilson Center for Research and Technology, opened with a typically provocative statement. “There is no such thing as industry,” he declared, maintaining that most industry-university partnerships are misunderstood. For example, some view industry as the customer and the university as the supplier through its production of students as future employees. Others view the university as the customer and industry as the supplier in terms of providing funding for advanced degrees. Often ignored is the characterization of industry and universities as partners in both knowledge creation, and in value creation. “Most companies focus on results and what they will get out of a partnership,” said Duke. “In reality, relationships and learning are the primary value propositions, and we must learn how to generate such enduring value from our collaborations.”

Duke concluded by identifying five keys to generating value from industry-university collaborations:

- (1) Know what you want; be clear and candid;
- (2) Learn what your collaborators want; be curious and sympathetic;
- (3) Focus on generating mutual value; be generous;
- (4) Participate personally; connect and deliver; and
- (5) Generating good relationships is a contact sport; to win, you must play.

Breakout Groups: Consensus and Summary

At the end of the day, the various breakout groups were asked to summarize their discussions, identifying what they deemed to be the most important message with which workshop participants ought to walk away. For example, one group felt that a physics major should be more than just a prelude to graduate school, and introductory courses should be overhauled to reflect new areas of physics, with some attention to practical skills needed by industry. Another group suggested that a database of university faculty organized by area of technical expertise would be useful in promoting interactions with companies in need of sponsored research. And strategies for recruiting more physics majors included more active recruitment efforts, pedagogy reform, and offering alternative degree programs, such as a five-year combined BS/MS degree in engineering physics.

The third annual Academic-Industrial Workshop will be held October 27, 2002, at the Marriott Hotel in Williamsburg, VA. For more information visit: www.aip.org/ipf

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