Chapter 6.
Connections, Lessons, and Other Issues

In the previous sections of this report, we have laid out our analysis of what makes a thriving undergraduate physics program. That analysis has been backed up with evidence and examples. In this section, we take a somewhat more subjective approach to look at connections between our analysis and work done by others. We also write about some new questions that have arisen as part of our study and implications of those questions for the future of physics.

Undergraduate Mathematics Site Visits

After this study was well under way, we learned about a similar effort in undergraduate mathematics education. (That in itself says a lot about how poorly the scientific and mathematics communities communicate the results of such studies.) In the early 1990s, the Mathematical Association of America, with funding from the National Science Foundation, carried out a series of 10 site visits to undergraduate mathematics programs. Although the mathematics site visit group used a methodology somewhat different from that used by SPIN-UP, the conclusions expressed in the report *Models that Work: Case Studies in Effective Undergraduate Mathematics Programs* [Tucker, 1995] are quite consistent with the results we have found from the SPIN-UP site visits. The MAA group selected departments based on evidence of effective practices excelling in

- attracting and training large numbers of mathematics majors, or
- preparing students to pursue advanced study in mathematics, or
- preparing future school mathematics teachers, or
- attracting and training underrepresented groups in mathematics.

On p. vii the report states, “The site visits revealed that there is no single key to a successful undergraduate program in mathematics. Almost any approach can be made to work in almost any institutional context if a substantial number of the mathematical faculty care deeply about undergraduate education, create an atmosphere among faculty and students that the study of mathematics is important and rewarding, and maintain close interactions with their students.” This finding agrees with what SPIN-UP found in the 21 physics site visit departments.

The MAA report goes on to delineate the common features of effective programs (p. 3) including three states of mind that underlie faculty attitudes in effective programs:

- respecting students, and in particular, teaching for the students one has, not the students one wished one had.
- caring about the students’ academic and general welfare.
- enjoying one’s career as a collegiate educator.

"A common theme of effective programs is the existence of a variety of mechanisms for interactions between faculty and students outside of class, both in one-on-one settings and in social groups." (p. 3) The effective departments also exhibited:

- a curriculum geared toward the needs of the students not the values of the faculty
- an interest in using a variety of pedagogical and learning approaches.

The site visit committee identified four major components of efforts to reform mathematics education: (p. 32)

a. Assessing the goals of the current program and aligning them with the needs of the students.

b. Building support for innovation that engages the faculty. (Some efforts start with broad support within the department, others are initiated by a few energetic individuals.)

c. Initiating the process of change and experimentation. Continuing experimentation was the hallmark of most of the institutions visited in this report, even though they already had successful programs.

d. Developing an environment of faculty involvement in the welfare, academic, and otherwise, of their students.

All of these statements closely mirror the results found in the SPIN-UP site visits. Our conclusion is that the features of effective undergraduate programs apply to all the science, technology, engineering, and mathematics disciplines.

Revitalizing Undergraduate Science Education

Sheila Tobias has been studying science and mathematics education for more than a decade. Her book *Revitalizing Undergraduate Science Education* (Research Corporation, Tucson, AZ, 1992) reports on a series of case studies in undergraduate chemistry, physics, and mathematics programs that "work." Tobias's conclusions neatly parallel those in this SPIN-UP report. Here are some selected conclusions:

> "…first, change is not implemented by experts, but originates in local commitment and reallocation of resources at the midlevel of management—in the case of colleges and universities, the department." (p. 158)
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> "A hallmark of effective programs is that the process of reform is all-engaging. Ideas are solicited from faculty and implemented locally by the department." (p. 158)
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> "The model for science education reform is not an experimental model, not even a research model, but a *process model* that focuses attention continuously on every aspect of the teaching-learning enterprise, locally and in depth…. In programs that work, faculty members pay continuous attention to 'what we teach, who we teach, and how we teach.'" (p. 160)

Thriving in the Business World

Parallels to our report's conclusions are also found in the vast business literature on managing change and building thriving companies. As one recent example, we cite Jim Collins's *From Good to Great* (HarperCollins, New York, 2001), which analyzes a number of companies that have successfully made the transition from being "good" to being "great." Collins and his research team identified a number of characteristics shared by these companies and missing in those companies that failed to make the transition. Again, a few selections show the parallels:

> "All good-to-great companies began the process of finding a path to greatness by confronting the brutal facts of their current situation…. The good-to-great companies faced just as much adversity as the comparison companies, but responded to that adversity differently. They hit the realities of their situation head on." (p. 88)
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> "Good-to-great transformations often look like dramatic, revolutionary events to those observing from the outside, but they feel like organic, cumulative processes to people on the inside. The confusion of end outcomes (dramatic results) with process (organic and cumulative) skews our perception of what really works over the long haul. No matter how dramatic the end result, the good-to-great transformations never happened in one fell swoop. There was no single defining action, no grand program, no one killer innovation, no solitary lucky break, no miracle moment." (p. 186)
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> "Level 5 leaders [leaders of those companies that have made the transition] are ambitious for the company and what it stands for; they have a sense of purpose beyond their own success." (p. 198)

Underrepresented Groups and the Issue of Diversity

It is a well known but still unsettling fact that women and minorities are distinguished by their lack of presence in the STEM disciplines, particularly in the physical sciences, mathematics and engineering. The National Science Foundation's *Science and Engineering Indicators 2002* gives the detailed statistics. Participation is increasing, but much more slowly than everyone would like. There is much speculation about this lack of participation, and we shall not rehearse those speculations here. The SPIN-UP site visits did uncover one surprise: We had anticipated that thriving departments, which managed to recruit many more students than the national average and which were well regarded within their institutions, would have substantial success in bringing women and minority students into physics. We found that most of the site visit departments did in fact do a bit better than the national average in attracting underrepresented students, but not a lot better. This finding was a surprise to all of the site visit teams because the folklore amongst those who are actively working to increase the participation of underrepresented groups in STEM is that active, supportive programs will be much more successful in attracting women and minority students. Our conclusion is that these conditions may be necessary, but they are not sufficient.

The MAA report [Tucker, 1995] comes to a similar conclusion:

> "Unfortunately, the four-year mathematics programs visited in this project had negligible numbers of Black and Latino mathematics majors, except of course for Southern University and Spelman College, which are historically Black institutions….. The programs that draw large numbers of other types of students apparently need to do something different and special for attracting and retaining this group in mathematics." (page 30)

Faced with these surprising results, the Task Force decided to invite about a dozen representatives of the National Society of Black Physicists and the National Society of Hispanic Physicists to its December 2002 meeting to discuss this issue and to explore possible studies the Task Force might undertake to understand this critical issue more fully. The participants at the meeting concluded that nearly all the general factors that seem to be important for attracting and retaining underrepresented groups in physics are the same factors that attract and retain "traditional" physics students. Nevertheless, these factors do not guarantee that a particular department will attract more students from underrepresented groups. The Task Force plans to use its site visit methodology to study a number of undergraduate physics programs that in fact do serve larger numbers of minority students. Many of these, of course, will be historically black colleges and universities. We also plan to make use of the results of a recent study (Barbara Whitten, Colorado College) that focused on physics departments that have a large fraction of women physics majors.

We argue that increasing the presence of underrepresented groups in physics is important on two counts: First, it is just the right thing to do. Everyone should have the opportunity to experience the joys (and frustrations) of science and to contribute to the betterment of humankind through science. Second, in the 21st century the population subgroup that has historically dominated science (white males) will shrink both in absolute numbers and as a fraction of the U.S. population. It is difficult, if not impossible, to say precisely how many scientists, engineers, and mathematicians the United States needs, but it is safe to say that number will not decrease from our current needs. We do know that with more scientists and with more diverse backgrounds represented, science is likely to advance more rapidly than it would otherwise. Simply from the perspective of maintaining a vibrant scientific and technological workforce to maintain our economy, our security, and the infrastructure needed to improve the health and environment for all people, we will need to tap the full spectrum of the nation's talent for the next generation of scientists, mathematicians, and engineers.

As a result of the December meeting, the Task Force will carry out two further site visits, one to an historically black college or university and the other to a hispanic-serving institution. The results of those site visits will be reported elsewhere. Some Task Force members and some of the representatives at the December meeting are writing a report on the meeting along with articles to be submitted to various physics publications.

Two-year Colleges

The SPIN-UP study focused on physics departments that offer at least the bachelor's degree in physics. Nationwide, however, many students study physics in two-year colleges, some in preparation for transfer to a four-year institution, some as part of their technology training for a two-year associate's degree. A study carried out by the American Institute of Physics [Neuschatz, et al., 1998] indicates that about half of the nation's pre-service teachers take their science courses at two-year colleges. Two-year colleges play an important role in undergraduate science education. But, the academic organization of two-year colleges is substantially different from that of four-year colleges and universities. Only the largest of the two-year colleges have physics departments. Most employ one or two physics faculty as part of a department of natural sciences. In order to understand the characteristics that make up a thriving physics program at a two-year college, Task Force member Tom O'Kuma (Lee College) and Mary Beth Monroe (Southwest Texas Junior College) developed project "SPIN-UP Two-Year Colleges" that has been funded by the National Science Foundation. Employing a site visit protocol similar to that used for SPIN-UP, the two-year college study will sponsor visits to 10 or so two-year colleges and produce a report analyzing the results of those site visits. The report is expected to be finished during the fall of 2003.

Teacher Preparation

Both the general public and those within the scientific community have been calling for improved preparation for K–12 teachers in mathematics and science. Much of this responsibility must fall on the shoulders of undergraduate science and mathematics programs. We were disappointed to find that most of our site visit departments were not actively engaged in pre-service teaching preparation either at the K–8 or at the high school level. Those that did have programs for teacher preparation were serving relatively few students. Although most of the departments acknowledged that they should be doing more, they cited difficulties working with the School of Education (or its equivalent) and the lack of student interest. Even when pre-service courses were offered, few students (and even fewer physics majors) took them.

The physics professional organizations have recently urged physics departments to take a more active role in both pre-service and in-service work with teachers. With generous funding from the National Science Foundation and the Fund for Post-Secondary Education, AAPT, APS, and AIP have launched the Physics Teacher Education Coalition to develop models of effective programs for pre-service teacher work within physics departments. More information on this program can be found at *http://www.phystec.org*. In addition, the report of a University of Nebraska–Lincoln conference on teacher preparation in physics departments [Buck, Hehn and Leslie-Pelecky, 2000] contains several articles describing what physics departments can do to aid pre-service teachers.

Future Directions

1. The Task Force is now in the process of preparing proposals for activities that will build on the SPIN-UP results. The aim is to work with physics departments that want to "revitalize" their undergraduate physics programs. A trial workshop held at the PKAL Summer Institute June 2002 drew about 65 participants from 20 or so physics departments. In the spring of 2003, the Task Force will carry out a trial "consulting visit" to aid a department

planning the revitalization of its undergraduate program. A proposal for more workshops and consulting visits to reach, say, 150 physics departments, would have a major impact on undergraduate physics in the United States

2. As we mentioned previously, the Task Force will also explore the issues of diversity in physics with the aim of promoting some concrete activities.
3. Plans are under way for a conference on algebra-based introductory physics courses to complement the conference on calculus-based introductory physics.
4. The AAPT Committee on Undergraduate Physics, under the leadership of Steve Turley of Brigham Young University, is undertaking a revision of AAPT's *Guide to Undergraduate Physics Programs*. The results of SPIN-UP will guide these revisions. Physics departments planning new initiatives or preparing for departmental reviews often use this booklet.
5. The Task Force has begun to work with leaders in other STEM disciplines who are focusing on undergraduate education. For example, a member of the leadership of ProjectNEXT, Tom Rishel, attended the 2000 New Physics Faculty Workshop, and we hope to send a member of the Task Force to their next conference. In June 2002, Hilborn and Hehn met with geologists Cathy Manduca (Carleton College), David Mog (Montana State University), and Heather MacDonald (William and Mary) to discuss possible extension of the physics site visit techniques to geology departments and other possible areas of collaboration. There has also been some contact with the American Chemical Society's Committee on Professional Training for a possible joint study of diversity issues.

Final Words of Wisdom and Encouragement

The Task Force on Undergraduate Physics is committed to the improvement of undergraduate physics because undergraduate physics plays an absolutely crucial role in educating the next generation of scientists and engineers, the next generation of K–12 teachers, and the future leaders of our society. We believe that the conclusions drawn from our analysis of the site visits and the general survey provide a blueprint for what is needed to build a thriving undergraduate physics program. The blueprint, however, must be adapted to fit each department's local "zoning regulations" (the students each department serves, the faculty and physical resources available, and the mission of the home institution). But we are convinced that with sustained efforts every physics department can have a thriving program in which students are challenged and supported in their many career and intellectual goals and faculty find great satisfaction in approaching undergraduate physics as a scholarly enterprise worthy of the problem-solving and critical-thinking skills that sustain them as researchers.