Help Wanted

What physics departments have done, can do, and should do to increase student enrollment and better prepare physics majors for the workforce.

BY KENNETH S. KRANE

The 1960s were in many ways a golden age for undergraduate physics education in the United States. Perhaps in response to the growing interest in space exploration, undergraduate physics enrollment grew so that an average of 5,500 bachelor's degrees were awarded each year during the 1960s, peaking at 6,000 by the end of the decade. This growth in undergraduate enrollment produced a corresponding growth in graduate programs—the number of doctorates awarded each year tripled during the 1960s, totaling 1,500 in 1970. However, in the ensuing decades, the growth rate in physics majors has fallen, despite the explosive growth in technology.

In fact, undergraduate enrollment fell 25 percent before stabilizing at about 4,500 bachelor's degrees per year through the late 1970s. This decline occurred primarily at institutions that awarded master's or doctorates in physics. Curiously, during this same period there was nearly a 20 percent increase in the total number of STEM (science, technology, engineering, mathematics) bachelor's awarded; though more undergraduates majored in science and engineering, fewer majored in physics.

The '90s proved to be an even more critical period for undergraduate physics enrollment. Bachelor's degree production in physics declined by 25 percent, while STEM-related bachelor's rose by 15 percent. The number of physics bachelor's degrees fell to fewer than 4,000 each year between 1997 and 2000, which had previously occurred only prior to 1958. As a share of total STEM bachelor's degrees, physics fell from 5 percent in the late 1960s to 2 percent by 2000.

In response to what was clearly a crisis for the physics community, the National Task Force on Undergraduate Physics was formed in 1999 to stimulate the revitalization of undergraduate physics education in the United States. Rather than identify the causes for the decline in physics enrollment, the Task Force set out to identify and assess departments where enrollment had thrived despite the national declines.

One of the key elements characterizing thriving programs was the presence of flexible and diverse degree curricula. In the 1960s and 1970s, most physics departments offered only a single bachelor's degree curriculum, whose purpose was primarily to provide the rigorous background necessary for success in graduate school. Today many successful departments offer a range of degree alternatives: applied or engineering physics (including joint 3-2 engineering programs); specialized programs within physics (such as optics or materials science); joint degree programs with other academic disciplines (chemistry, computer science, business); and general programs for pre-service teachers, pre-law, and pre-medical training. These programs encourage students to think of physics more broadly as preparation for the workforce, rather than more narrowly as preparation for graduate school.

Remarkably, the decline in undergraduate physics enrollment abated in 1999, and bachelor's degree production grew to more than 5,100 in 2005, the highest total since the early '70s. Based on the sizes of currently enrolled junior and senior classes, these increases are expected to continue at approximately 5 percent per year for at least the next two years. The revival in physics enrollment was led by Ph.D.-granting institutions, which on average

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awarded about half of all the physics bachelor's conferred in the United States in 2005 (see "Endpoint," page 52).

Despite the rosy national picture, not all departments have shared in these increases. Among Ph.D.-granting departments, about one-third award no more than six bachelor's degrees per year; approximately 33 percent of both B.A./B.S.- and M.S.-granting institutions award only two or fewer bachelor's degrees per year.

Many departments have posted increases between 2003 and 2005 that are far above the national average for their category. Table 1 represents "honor roll" institutions with Ph.D.- and M.S.-granting physics departments that significantly exceeded the national average increases (respectively 43 percent and 17 percent) in their categories relative to the 1997 to 1999 base period. Table 2 indicates "honor roll" institutions whose highest physics degree is the B.A./B.S. (for which the national average increase was 19 percent).

This survey was restricted to Ph.D.-granting institutions that awarded a total of 20 or more physics degrees during the 1997 to 1999 base period and to M.S. and B.A./B.S. institutions that awarded a total of 10 or more. As a result, depart-

Highest Degree	Institution	Degrees/y 2003-05	Change from 1997-99
Ph.D.	Michigan State Univ.	19	+164%
Ph.D.	Univ. of California, Santa Barbara	36	+163%
Ph.D.	Univ. of Arkansas at Fayetteville	19	+148%
Ph.D.	Oregon State Univ.	19	+138%
Ph.D.	Univ. of California, Santa Cruz	31	+119%
Ph.D.	Univ. of Maryland, College Park	33	+118%
Ph.D.	Univ. of Massachusetts Amherst	19	+107%
Ph.D.	Univ. of Arizona	35	+100%
Ph.D.	Univ. of Minnesota, Twin Cities	27	+95%
Ph.D.	University of Florida	24	+92%
Ph.D.	Brown University	15	+92%
M.S.	Missouri State Univ.	9	+160%
M.S.	California State Univ., Northridge	11	+154%
M.S.	University of Memphis	8	+150%
M.S.	Cleveland State Univ.	10	+138%
M.S.	Ball State University	8	+130%

Table 1. Ph.D.- and M.S.-granting departments with the largest recent increases in physics degrees conferred.

Institution	Degrees/y 2003-05	Change from 1997-99
Cal Poly, San Luis Obispo	24	+243%
Univ. of Northern Colorado	12	+133%
Benedict College	10	+131%
Gettysburg College	8	+130%
College of New Jersey	12	+125%
University of Wisconsin – La Crosse	19	+124%
Shippensburg University	9	+117%
Whitworth College	9	+117%
North Georgia College & State University	7	+110%
Rowan University	7	+110%
Williams College	18	+104%
Jacksonville University	9	+100%
University of Wisconsin – River Falls	10	+94%
Murray State University	9	+93%
Humboldt State University	7	+91%
Trinity University	7	+91%
Dickinson College	13	+90%
College of Charleston	19	+87%
Lewis and Clark College	9	+86%

Table 2. B.A./B.S. institutions with the largest recent increases in physics degrees conferred.

ments with very small degree totals but very large percent increases have not been included.

It is important to keep in mind that the so-called "honor roll" departments recognized in Tables 1 and 2 were already above the median in their respective categories during the base period, and they built on their prior successes to grow even more successful. Nor is it a given that every successful program will continue to thrive: Of the 21 schools featured as case studies in the report of the National Task Force, one-fourth showed declines in enrollment and one-fourth showed increases below the national average in their respective categories.

Of interest, however, are the key elements that enabled these departments to achieve such stunning successes from 1999 to 2005. Before doing so, it is helpful to review some of the characteristics common to these thriving departments as identified by the National Task Force:

1. Sustained departmental leadership.
2. A clearly articulated mission and the vision to implement it.
3. A substantial majority of the faculty engaged in the undergraduate program.
4. Support from the college or university administration.
5. An active recruitment program.
6. Effective formal and informal advising; other informal faculty-student interactions.
7. Career mentoring.
8. Careful attention to the introductory courses.
9. Flexible degree programs for majors.
10. Undergraduate participation in research.
11. An active physics club and a commons room for undergraduates.

The key element missing from this list is the coherence and coordination that must be brought to these otherwise disparate elements. It is not enough to simply check off these characteristics; instead, it is important to evaluate how these elements work together to create an environment in which undergraduates can achieve success. For example, efforts to improve the introductory course complement recruitment activities, because the introductory course often attracts new majors to physics.

The recipe for contributing to the workforce has three steps:

1. Grow enrollment in the physics major.
2. Create diverse degree programs that prepare students for the workforce.

A SAMPLING OF "THRIVING" PHYSICS DEPARTMENTS

University of Arkansas at Fayetteville (+147%)
The department offers multitrack curricula for the B.A. (targeted at students with interests in medicine, law, business, or journalism) and the B.S. (professional, optics, electronics, computational, and biophysics). A physics education research program has raised faculty awareness of good teaching practices throughout the curriculum. The department builds a sense of community for the students through an active Society of Physics Students chapter, student lounge, research projects, and involvement of students in departmental outreach activities.

University of Wisconsin – River Falls (+94%)
Recruiting efforts at UWRF are enhanced by a close connection with high-school physics teachers from throughout the state due to a summer master's program for teachers. The physics department meets with university recruiters to provide them with good talking points about physics. An undergraduate lounge, an active SPS chapter (one of the 10 largest in the U.S.), and a strong emphasis on undergraduate research help provide a supportive environment for students.

University of Minnesota, Twin Cities (+95%)
Active recruiting among science and engineering majors, who take a common curriculum in the first two years, helps build enrollment. The department offers five tracks through the major: professional physics, engineering, computational, materials, and biomedical, along with numerous double majors (astrophysics, computer science, math). Undergraduate research, an active SPS chapter, and an annual awards program and graduation party make students feel part of the department. Group learning methods are employed in upper-level classes.

University of Northern Colorado (+133%)
Students serve as teaching assistants (lab and discussion section leaders in introductory courses, graders in courses at all levels) and have keys to the physics building for after-hours access. Continuing evaluation and reform of the curriculum, an undergraduate research requirement, and meetings with advisers every semester have contributed to the department's success. Attention to the general education science classes helps attract new physics majors.

Oregon State University (+138%)

A modularized junior-senior curriculum breaks the subjects into manageable pieces and encourages a sense of mastery of the material. The program ramps more slowly into the sophisticated and theoretical subjects of the traditional junior-year curriculum and leaves fewer students frustrated with its difficulty. Group interactions coupled with a multiplicity of approaches to problem solving (analytical, computational, graphical, simulations) prepare students who will eventually attend graduate school and those who will directly enter the workforce.

University of Massachusetts Amherst (+107%)

In 1998 the department established a five-year program to double the number of physics majors. Components of the program include early contact with admitted students (in the spring prior to their first year), enhanced contacts with two-year colleges, and active presence in the university honors program and in an advising program for undeclared majors. There is tight central coordination of advising, with each admitted class keeping the same adviser for four years.

Lewis and Clark College (+86%)

The SPS program is supported with $1000 annually from the department for its activities. Upper-division students serve as teaching assistants in the lower-division labs and thus get to know the newer students. Students in the advanced lab give departmental talks on their projects and then get taken out to dinner like a visiting speaker. An endowed summer research program often leads to presentations at meetings or publications in peer-reviewed journals. Flexible scheduling of advanced courses allows students to participate in semester abroad programs.

University of Florida (+92%)

Student evaluations of teaching and exit interviews with graduating seniors are used to advise the department about future teaching assignments. All admitted students with SAT math scores above 720 receive a letter inviting them to enroll in the introductory course for majors. Other departmental attributes include an active SPS chapter, student lounge, undergraduate research, and an aggressive advising program (which includes a monthly newsletter informing students about classes, jobs, and research opportunities).

3. Incorporate pedagogies that simulate problem-solving methods useful in the workplace.

It is not necessary to reinvent the wheel, nor can anyone argue that "it won't work here." The highly successful programs cover a range of institutional sizes and characters. Among these model programs are many examples of how to create a thriving undergraduate program with an increasing number of graduates who are well prepared both for graduate school and for careers in industry, government, military, K-12 schools, and other professions. Δ

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