Chapter 5.
The Survey

Background

Recognizing that our site visits to 23 institutions (representing 3% of the undergraduate physics programs in the United States) may not have given us a complete or representative overview of the state of U.S. undergraduate physics, we sought to augment our conclusions from the site visits with results from a survey that would provide a more complete view of the status of undergraduate physics education. To accomplish this result, the Task Force composed a survey form (see Appendix VII) to distribute to all undergraduate programs in the United States. Its goals were to provide data of greater statistical reliability than those obtained from the site visits, to give a more detailed and comprehensive snapshot of undergraduate physics programs, and to reveal trends or circumstances that might have been missed in the site visits. The distribution of the survey form and the analysis of the responses were done with the collaboration of the Statistical Research Center of the American Institute of Physics.

The survey form, which sought to gather information about curricula, recruiting, advising, alumni contacts, and reform efforts, was posted on a website. Chairs of all 759 undergraduate programs were notified on April 17, 2002, and asked to participate in the survey. They were told that the survey results would be analyzed only statistically and that we would not identify any of the respondents in our publications. Follow-up reminders were sent to nonrespondents on April 29, May 22, and June 5. Data gathering closed on June 17, at which time 561 replies had been received, representing 74% of the programs surveyed. This represents an extraordinarily high response rate, which typically indicates that the questionnaire focused on issues of concern to the respondents.

Originally there was concern that the response would not represent a fair cross-section of the undergraduate programs; we feared that small or inactive departments would be less likely to respond, as they have little to report. Tables 1 and 2 compare the response rates according to number of faculty and according to number of graduates (totaled over the three years 1998–2000). Data on department size and number of graduates in Tables 1 and 2 were collected independently by the AIP Survey Research Center as part of its regular annual survey of physics programs.

The results summarized in Tables 1 and 2 demonstrate that our fears of a skewed response rate were not justified. Table 1 shows that the survey response rate was quite constant independent of faculty size. Table 2 shows that the response rate was constant independent of number of graduates and also independent of highest degree awarded. Based on the analysis of these three factors (faculty size, number of degrees awarded, and highest degree awarded), the response rates appear to be free of bias in any particular direction. Small deviations between different categories can be ascribed to statistical fluctuations and are generally within the anticipated statistical sampling errors.

Table 1. Survey response rate according to size of department (number of faculty)

Number of faculty (FTE)	Number of departments by highest degree			Total number of departments	Response rate %
	B.S./B.A.	M.S.	Ph.D.		
≤ 2.0	95	—	—	95	67
2.1 – 3.0	87	1	—	88	73
3.1 – 4.0	87	1	—	88	78
4.1 – 6.0	108	4	2	114	71
6.1 – 9.0	80	18	8	106	73
9.1 – 15.0	34	33	27	94	83
15.1 – 25.0	5	10	57	72	74
25.1 – 39.9	4	3	46	53	81
≥ 40.0	—	—	33	33	70
Total number of departments	500	70	173	743	74

Table 2. Survey response rate according to number of bachelor's degrees awarded (1998–2000 total)

Number of bachelor's degrees (3-year total)	Number of departments by highest degree			Total number of departments	Response rate %
	B.S./B.A.	M.S.	Ph.D.		
New departments*	11	1	—	12	58
None	22	1	—	23	74
1 to 5	156	10	5	171	71
6 to 9	124	17	21	162	78
10 to 14	92	14	28	134	69
15 to 29	83	25	56	164	76
30 to 44	22	3	28	53	79
45 or more	5	—	35	40	73
Total number of departments	515	71	173	759	74
Total response rate	74	68	77	74	

*These 12 departments were added to the AIP database during the three years 1998–2000.

Courses and Curricula

The first section of the survey dealt with courses and curricula. One of the conclusions from the site visits was that thriving departments were often characterized by a diversity of physics degree programs or "tracks." We sought to use the survey to determine whether that finding, based on a limited number of data points, is broadly characteristic of the physics community. Moreover, we requested information on the alternative degrees and the number of physics credits required.

Of the responding schools, 81% characterized themselves as following the traditional semester system in awarding course credits, 6% awarded credits following a traditional quarter system, 10% awarded credits on an alternative system with one credit per course, and 3% followed various other schemes for awarding credits. We asked each school to begin by providing information about its "standard" physics program. This is usually the most rigorous program, requiring the greatest number of physics credits and often designed to prepare students for graduate study or professional work in physics. Table 3 shows the survey results for the number of physics credits required for this degree program compared with the total number required for a bachelor's degree.

Table 3. Credits required for "standard" physics degree

Academic Calendar	Total credits for bachelor's degree		Physics credits for "standard" degree		Number of respondents
	Low	High	Low*	High*	
One credit per course	30	36	8 (25%)	12 (39%)	57
Semesters	110	146	32 (25%)	50 (40%)	452
Quarters	175	196	54 (29%)	87 (48%)	30

*Low and high figures represent 10% and 90% range; that is, 10% of the respondents are below the low figure and 10% are above the high figure. The numbers in parentheses represent the fraction of the total credits represented by the required physics credits.

Institutions vary in terms of the number of total credits required for a baccalaureate degree, and they vary in terms of the proportion of those credits that must be completed in physics to be awarded a physics degree. The physics fraction of total graduation credits required for the "standard" physics degree is typically in the range of 25–39% for schools on the one credit per course system, 25–40% for schools on the traditional semester system, and 29–48% for schools on the traditional quarter system. Thus, to earn a physics degree, virtually all physics departments require that at least 25% of all credits be taken in physics and comparatively few departments require more than 40%.

We also surveyed the physics credits required for different types of "standard" degree programs. Table 4 shows these data, along with the corresponding mathematics and chemistry requirements for the "standard" degree program.

Our site visits indicated that thriving departments often involved students in research experiences or required a thesis based on a research or library project. Our survey indicated that a research experience is required by 36% the schools in which the "standard" physics program is a

B.S. in physics, 29% in which it is a B.A. in physics, and 37% of the other bachelor's program. Similarly, a thesis is required in 14% of the B.S. programs, 19% of the B.A. programs, and 17% of the other programs. Perhaps surprisingly, the research and thesis requirements were more common in B.A./B.S. institutions (28% and 13%, respectively) than in Ph.D. institutions (21% and 9%).

Table 4. Physics, mathematics, and chemistry requirements in "standard" degree programs

"Standard" physics degree program	Physics credits required*		Mathematics credits required*		Chemistry credits required*		Number of respondents
	Low	High	Low	High	Low	High	
B.S. in physics	27%	41%	10%	18%	3%	8%	413
B.A. in physics	23%	37%	6%	16%	3%	9%	100
Other bachelor's	22%	40%	7%	17%	4%	9%	32

* Credits are given as a percentage of the total credits required for the degree. Low and high figures represent 10% and 90% range; that is, 10% of the respondents are below the low figure and 10% are above the high figure. Fifty-six percent of the B.A. programs and 22% of the B.S. and other bachelor's programs require no chemistry; the table shows the typical ranges only from the respondents who require chemistry.

The B.S. is by far the most common "standard" degree program: It is identified as the "standard" degree by 71% of institutions in which the bachelor's is the highest degree, 90% of M.S. institutions, and 84% of Ph.D. institutions. The B.A. is the "standard" degree at 23% of the bachelor's institutions, 2% of the M.S. institutions, and 11% of the Ph.D. institutions. Other degrees identified at 6–8% of institutions as the "standard" program include a bachelor's in engineering physics (2% of all institutions) and a bachelor's in applied physics (2% of all institutions).

For the various "standard" tracks, we asked institutions to report the number of credits required for various courses in the physics curriculum. These data are still under analysis to correct for variations in systems of assigning credits.

Table 5 shows the alternative degree tracks offered by institutions with various "standard" physics degree programs. Overall, 84% of departments offer at least one alternative degree track. We asked institutions to specify the number of physics credits required in their various alternative tracks and to list the number of students who completed degrees in the past three years under the alternative tracks. These data proved difficult to analyze, so it may be necessary to do follow-up surveys to selected departments to complete the correlation between the availability of alternative tracks and the number of physics graduates.

Table 5. Fraction of reporting departments offering alternative physics degree tracks for various "standard" programs

Alternative degree track	"Standard" physics degree program			Overall fraction %
	B.S. in physics %	B.A. in physics %	Other bachelor's %	
B.A.	46	n/a	28	39
Physics degree for teachers	30	24	28	29
Specialized degree (e.g., geophysics)	17	13	14	16
Applied physics	16	6	17	14
Engineering physics	15	6	17	13
Combined degree (e.g., physics + math)	11	11	28	12
Astronomy degree	7	11	—	7
Other	20	18	24	20
No alternative track	12	35	24	16
Number of responding departments	368	80	29	477

Questions concerning the availability of minors did not yield any surprising results. Of the reporting departments, 90% offer a minor in either physics (75%), astronomy (1%), or both (14%). As might be expected, the departments with the largest numbers of minors are also those with the largest number of majors. However, the overall numbers are relatively small—only 16% of reporting departments awarded an average of more than two minors per year in physics or astronomy during the past three years. While virtually all physics departments offer minors, there are cultural differences in the extent to which this option is stressed. By way of example, some of the research departments that award very large numbers of physics bachelors annually award no minors in physics. Conversely, some of the smaller bachelors-granting departments award more minors in physics annually than they do bachelors in physics.

Finally, the responders were asked an open-ended question about whether their institutions were planning to add any alternative degree tracks in the near future. Most responders did not answer this question, which we take to suggest that they are not planning to add new tracks. Of those who did respond, the most frequent answers were "no" (156 responses) and "maybe" (29). Other frequently cited responses were engineering (28), teaching (13), applied physics (12), computational physics (11), medical physics (11), and astronomy (9). Other responses included biological physics, materials physics, physics for pre-law, and geophysics.

Recruitment Activities

Question 8 on the survey form asked departments to specify which recruitment activities they pursue. Responses (from 561 departments) were as follows:

Recruiting high school students

Host prospective students and their families in the department	60%
Hold annual departmental open house for students and parents	47%
Recruit high school students likely to major in physics	34%
Faculty and students regularly visit local high schools	24%
Hold summer workshops for high school students	14%
Recruit high school students who are underrepresented minorities	11%

Recruiting enrolled college students

Identify and recruit talented students in service courses	61%
Group potential physics majors in special section of intro course	22%
Offer “introduction to the profession” courses for first year students	15%
Actively recruit transfer students from two-year colleges	11%

The right-hand column adds to more than 100% because departments were asked to indicate all recruiting activities in which they took part.

As might be expected, there is a correlation between the number of recruiting activities and the size of the department. Departments in which the highest degree is the bachelor’s reported an average of 2.7 recruiting activities, while Ph.D.-granting departments reported an average of 3.9 recruiting activities. Of the 113 departments reporting 0 or one recruiting activities, 68% had six or fewer faculty; conversely, of the 122 departments reporting five or more recruitment activities, 71% had more than six faculty.

The correlations between recruitment activities and number of degrees awarded are shown in Tables 6 and 7 for departments in which the highest degree is respectively the bachelor’s and the Ph.D. Table 6 indicates that, of the bachelor’s-granting departments, 50% of those that engage in the fewest recruiting activities (0 or one) awarded fewer than two degrees per year over the three-year period. At the other end of the scale, the correlation is much weaker—of the departments that engaged in the highest number of recruitment activities (four or more), fewer than half exceed the average number of degrees (three/year) awarded by baccalaureate departments.

For the Ph.D.-granting departments (Table 7), the correlation between the number of graduates and the number of recruitment activities is weak at best. Sixty percent of the departments with five or more recruiting activities fail to reach the average of 10 graduates per year that characterizes the Ph.D.-granting institutions, and a third of the departments with the smallest number of recruiting activities exceed the average.

Table 6. Effect of number of recruitment activities on three-year total of physics bachelor's degrees at baccalaureate institutions

Three-year total of bachelor's degrees	Number of recruitment activities					Overall fraction of departments
	≤ 1	2	3	4	≥ 5	
0 to 5	50%	38%	26%	27%	23%	35%
6 to 9	23%	24%	26%	29%	30%	26%
10 to 14	12%	20%	19%	17%	25%	18%
15 or more	15%	18%	28%	27%	21%	21%
Number of responding respondents	100	81	91	52	56	380

Table 7. Effect of number of recruitment activities on three-year total of physics bachelor's degrees at Ph.D.-granting institutions

Three-year total of bachelor's degrees	Number of recruiting activities			Overall fraction of departments
	0 to 2	3 to 4	≥ 5	
0 to 14	27%	28%	28%	28%
15 to 29	42%	37%	32%	36%
30 or more	31%	35%	40%	36%
Number of responding departments	26	57	50	133

Another open-ended question asked departments to specify which of their recruiting activities they considered to be most effective. The most frequent response (which was not given among the original choices) was to assign good teachers to the introductory courses (cited by 29 responders). Other frequently mentioned successful activities included hosting of prospective students, recruiting talented students from the introductory course, high school recruitments, and open houses. Less frequently cited responses (fewer than 10) included special programs or courses, recruitment by the admissions staff, scholarships, telephone contacts, web or email contacts, mailings or brochures, SPS activities, and research opportunities.

Interactions between Faculty and Students

Among the measures of satisfaction most often mentioned by students during our site visits were advising and the informal interactions between students and faculty. Our survey sought to gather additional information on the number and type of these interactions and their correlation with the number of majors.

Overall, most institutions assign several faculty members as undergraduate advisors. A significant number, however, use only a single faculty member (or the department chair) as the undergraduate advisor. Curiously, this distinction correlates inversely with the size of the institution and is mostly independent of the number of majors. Multiple faculty members handle the advising in 75% of bachelor's institutions, 41% of M.S. institutions, and 51% of Ph.D. institutions, while a single faculty member handles the responsibility in 22% of bachelor's institutions, 55% of M.S. institutions, and 41% of Ph.D. institutions. Multiple faculty do the advising at 74% of schools with four or fewer faculty, 80% of schools with 4.1–9 faculty, 46% of schools with 9.1–25 faculty, and 59% of schools with more than 25 faculty; a single faculty member (possibly the department chair) is assigned to the advising in respectively 24%, 18%, 49%, and 27% of schools in these categories. Multiple faculty members do the advising in 67% of schools with an average of fewer than two graduates per year and also in 67% of schools with an average of more than 10 graduates per year, while a single faculty member does the advising in 27% of schools with an average of fewer than two graduates per year and in 23% of schools with an average of more than 10 graduates per year. (A small number of departments use a nonfaculty advisor in the physics department or a university advisor outside of physics.)

Responses regarding the frequency of student-advisor interaction varied from at most once per year to several times per term. Overall 62% of institutions reported that interactions occurred several times per term, with the bachelor's institutions ranging somewhat higher (70%) and the Ph.D. institutions lower (42%). As might be expected, those institutions using multiple faculty advisors were more likely to report several interactions per term (72%) than those using a single faculty member (25%). Unfortunately, during the site visits we did not ask students about the frequency of their interactions with their advisors; it would have been interesting to verify whether the data provided by the department head is "wishful thinking" or reality.

Question 11 of the survey form asked departments to indicate which of a list of activities they engaged in to make their students feel a part of the department. Responses were as follows:

Have an active physics club or SPS chapter	76%
Provide a dedicated undergraduate study room or lounge	74%
Provide building keys to undergraduate majors	52%
Conduct exit interviews with graduating seniors	43%
Assign a faculty mentor to each student	43%
Assign a peer mentor to each student	2%
Other activities	32%

Ph.D.-granting departments tended to run 10–20% above these averages, while bachelor's-granting departments tended to run about 10–20% lower. There was a similar correlation with the size of the department, with 53% of departments having three or fewer faculty engaging in two or fewer of these activities, while 68% of departments with 25 or more faculty engaged in four or more activities.

How do these activities correlate with the department's success in attracting and retaining majors? Tables 8 and 9 display the correlations for bachelor's-only institutions and Ph.D.-granting institutions, respectively. Here the correlations appear to be much stronger than was the case for the correlation between recruitment and number of majors (Tables 6 and 7). It seems clear that departments should focus their efforts on improving these interactions rather than on recruitment. This is consistent with strong anecdotal evidence obtained in conversations with students during the site visits—many students reported switching from engineering or math to physics because the physics department presented a more welcoming and accommodating image.

Table 8. Effect of number of departmental interactions on three-year total of physics bachelor's degrees at baccalaureate institutions

Three-year total of bachelor's degrees	Number of departmental interactions					Overall fraction of departments
	≤ 1	2	3	4	≥ 5	
0 to 5	19%	26%	30%	21%	5%	35%
6 to 9	13%	27%	24%	21%	16%	26%
10 to 14	11%	18%	35%	20%	17%	18%
15 or more	5%	18%	30%	28%	18%	21%
Number of responding respondents	48	85	107	81	48	370

Table 9. Effect of number of departmental interactions on three-year total of physics bachelor's degrees at Ph.D.-granting institutions

Three-year total of bachelor's degrees	Number of departmental interactions			Overall fraction of departments
	0 to 2	3 to 4	≥ 5	
0 to 14	36%	50%	14%	28%
15 to 29	17%	49%	34%	36%
30 or more	15%	52%	33%	36%
Number of responding departments	29	65	37	131

The availability of career information represents another area in which outreach by the department can enhance the student experience, both to attract majors and to help launch imminent graduates toward the next stage of their professional careers. Question 12 of the survey asked departments to list activities undertaken *within the past year* to provide career information to undergraduates. Overall responses were as follows:

Career materials from professional societies	63%
The university career services office	51%
Departmental colloquia by physicists in industry	47%
Alumni visits to the department	45%
Field trips to local industries	25%
Other	26%
None offered	6%

In contrast to the case of departmental interactions, in providing career information the level of activity of bachelor's-only institutions tended to be a bit *above* that of Ph.D.-granting institutions. With the exception of departmental colloquia (which are more common in Ph.D.-granting institutions), the activity level of bachelor's-only institutions in offering career information tended to fall about 10% above these overall averages, while that of the Ph.D.-granting institutions fell about 10% below. The level of activity in this area correlated weakly with the size of the department, with large departments tending to provide a somewhat greater level of career information than smaller departments. It appears from these data that larger, bachelor's-only departments are the most active in providing career information to their majors.

Two open-ended questions were asked in these areas. The first inquired about the department's most successful activities in shaping student attitudes toward the department. The most frequent responses were: informal interactions between faculty and students (cited on 112 forms), undergraduate study room (44), SPS activities (42), research experiences (33), and advising or mentoring (20). The second open-ended question asked about the department's most useful activity in providing career guidance. Responses included: faculty advising (55 citations), alumni visits (31), colloquia (18), research opportunities (15), career service office (10), and career materials from professional societies (9).

Alumni Tracking

Of the 561 responses to the survey, 453 reported answers to question 13, which asked about the career destinations of graduates of the past three years. Table 10 compares the responses from the three types of institutions. It should be noted that these data are given by number of responses and are NOT weighted by the number of graduates.

Table 10. Reported alumni destinations (as percent of responses) by highest degree awarded by institution.

Alumni destination	Highest institutional degree			Overall %
	B.S./B.A.	M.S.	Ph.D.	
Graduate school in physics	31	38	43	35
Other graduate school	15	7	12	14
Continue in 3/2 engineer. prog.	11	6	1	8
Employed in technical field	22	28	21	22
High school teaching	8	7	4	7
Employed in nontechnical field	3	2	3	3
Active military	2	1	2	2
Other	2	3	2	2
Don't know	7	8	13	9
Number of responding departs.	300	42	111	453

The data in Table 10 agree reasonably well with the data collected in the AIP Survey Research Center's annual survey of physics departments, which in recent years indicates that 32% of graduates enter graduate programs in physics, 20% enter graduate programs in other fields, and 48% enter the workforce.

Question 14 asked departments to identify activities they used to keep in contact with their alumni. With one exception, responses varied little among B.A./B.S., M.S., and Ph.D. institutions. Overall responses were:

Updates from past students by email and phone	51%
Mailing or email addresses from students at graduation	46%
Information on employment or graduate school plans at graduation	45%
Mailing list for departmental newsletter	26%
Surveys of alumni	24%
Other	4%
None of the above	32%

The one case in which there was a significant variation among types of institutions was in that of the departmental newsletter, for which 45% of Ph.D. institutions indicated that choice but only 20% of B.A./B.S. institutions.

Curricular Reform

More than 60% of the reporting departments (342 out of 561) affirmed that they had made "significant" changes in curriculum in the past several years. The overall responses to specific areas of change were as follows: upper-division courses—71%; calculus-based introductory courses—70%; general education courses—56%; introductory courses for majors—51%; algebra-based introductory courses—42%. Among the three types of institutions (B.S./B.A., M.S., Ph.D.), B.S./B.A. institutions were more likely than Ph.D. institutions to have made changes in their upper-division courses (76% vs. 60%) and general education courses (60% vs. 44%), while Ph.D. institutions were more likely than B.S./B.A. institutions to have made changes in calculus-based introductory courses (75% vs. 69%) and introductory courses for majors (64% vs. 47%).

It was more common for departments to report reforms in both content and pedagogy than in either area alone; the fractions of the reforms involving both content and pedagogy ranged from about 60% in general education courses, to 50% in introductory courses for majors, to 40% in calculus-based introductory courses and upper-division courses, and to 30% in the algebra-based introductory courses. Changes involving content only were most common in the upper-division courses (40%) and rather rare for introductory courses (10–20%). These data are not surprising, in that departments often introduce new courses for majors and rarely alter the traditional curriculum of the introductory courses. Changes in pedagogy more commonly occurred at the introductory level (80–90% of the changes involved pedagogy, either alone or in concert with changes in content) than at the advanced level (56%). There was relatively little systematic variation across institutional types in these data.

These results paint an encouraging profile of the state of undergraduate physics education and suggest a greater widespread receptiveness for curricular change than had been anticipated before the survey (although we must admit that we left it to the departments to determine for themselves what is a "significant" curricular reform).

The most common funding mechanism for curricular reforms was by far the internal reallocation of resources within the department. Overall 63% of those who reported curricular changes indicated this as a source of funding. (Responders were free to indicate several sources.) Among institutional types, these responses ranged from 57% at the B.S./B.A. institutions to 76% at the Ph.D. institutions, presumably because the latter often have more resources to reallocate. Other sources of funding were university or endowment funds from outside the department (27%), grants from NSF or other federal agency (22%), grants from private foundations (9% overall, but more common at B.S./B.A. institutions than at Ph.D. institutions), funds or equipment from business or industry (4%). Except as noted above, there was little variation across institutional types in these responses. It should be especially noted that the share from the federal agencies remains relatively flat across institutional types, indicating that the large research institutions are clearly not dominant in the quest for federal funding for curricular reform (although the dollar-weighted funding averages might be skewed in that direction).

We also asked three open-ended questions about the curricular reforms. Regarding the source of the motivation of the reforms, by far the most common response was energetic individual faculty members (112 responses). The next most common reform motivation was the desire to improve courses (41 responses), followed by college-wide initiatives (26), responses to external reviews (18), responses to student feedback (18), the desire to recruit more majors (16), internal reviews (15), and the development of new programs (11). "Negative" motivations (threats from the dean, reduction in faculty size) were cited only rarely (respectively, eight and five responses). The impact of physics education research was cited only three times, although that may have been an indirect motivation in driving the "energetic individual faculty members" to undertake the reform efforts.

The most common response to our inquiry about what the reforms were intended to accomplish was attract more majors (71), although content-related issues (better understanding of topic, better preparation for graduate school, better courses, better preparation for work force) drew significant responses as well (respectively 48, 47, 40, 25).

It appears that departments undertake these changes with only vague ideas of assessment. Our query regarding indicators of success drew "none" as its most common response (59), although student attitudes (43), increased number of majors (40), and increased enrollments (21) were also cited. Only 39 responses mentioned a formal assessment mechanism such as the Force Concept Inventory exam or the Graduate Record Examination.

Overall Evaluations of Undergraduate Physics Programs

Our survey concluded with open-ended questions about the undergraduate program's greatest strengths and greatest needs or challenges. Individualized faculty attention to students was the overwhelming choice for the greatest strength (203 responses). Next most often cited responses were research opportunities (89), excellent curriculum (79), and quality of faculty (70). Few departments cited flexible major programs (17) or an active SPS chapter (3) among their strengths; this is rather surprising in view of the survey results showing that 84% of departments offer alternative tracks to the major and 76% of departments regarded their SPS chapter as a major factor in promoting a welcoming attitude toward students. Only 15 departments cited their excellent equipment as one of their greatest strengths.

By far the greatest challenge seen by most department heads is the need for more students (204 responses). The need for resources is next most commonly cited, including more faculty (73), improved lab equipment and space (41), increased funding (39), increased administrative support (17), improved research opportunities (20), and better facilities and more space (13). Improved quality is also a significant need, including courses (38), faculty quality (17), better student preparation in math (20), and better students (9). Sadly, increased minority representation drew only five responses.