What Works for Women in Undergraduate Physics?

The predominance of men in physics remains a puzzle. To attract talented women and minorities, the culture of college physics needs a makeover.

Barbara L. Whitten, Suzanne R. Foster, and Margaret L. Duncombe

In 1998, women received about 40% of the bachelor's degrees in mathematics and chemistry, but only 19% of the bachelor's in physics. That underrepresentation worsens at higher levels: The same year, women constituted 13% of physics PhD recipients and 8% of physics faculty members.[1] According to NSF, the community of working PhD-level physicists in 2000 was 84% white and 93% male.[2] What accounts for such stark numbers?

A "leaky pipeline" explains part of the problem. Judging from figure 1, women opt out of physics at every step up the academic ladder. Pacific University physicist Mary Fehrs and Roman Czujko, director of the Statistical Research Center of the American Institute of Physics, found that those women who chose not to remain in physics had performed on a par with their male colleagues who stayed in the field. (See PHYSICS TODAY, August 1992, page 33.) Elaine Seymour and Nancy Hewitt, both sociologists at the University of Colorado at Boulder, confirmed that finding.[3] It implies a loss of talent, which the physics community can ill afford. To investigate the climate for women in graduate physics departments, the American Physical Society's Committee on the Status of Women in Physics (CSWP) began conducting a program of visits to physics departments in 1990. On the basis of those and continuing visits, the committee has recommended changes to make the departments more comfortable for women faculty and students.[4,5]

The biggest leak in the pipeline, though, appears in the college years following high school. If physics departments could learn how to persuade more of the girls who take high-school physics to major in physics in college, they would greatly increase the pool of women who might become professional physicists.

To complement the APS work on graduate programs, a team was formed to focus on undergraduate physics programs, taking as a starting point the fact that participation of women in different college physics departments varies widely. Some departments are successful at recruiting and retaining women as majors. We asked ourselves: What sets those successful departments apart? To answer the question, we've let the men and women speak for themselves, and have assembled a set of best practices or common features found in departments where women are thriving. But teasing out clear gender-related distinctions is difficult—what works for women will often work for men as well.

Barbara Whitten *(bwhitten@coloradocollege.edu) is a professor of physics at Colorado College in Colorado Springs.* **Suzanne Foster** *is a research associate at Ecos Consulting in Durango, Colorado;* **Margaret Duncombe** *is a professor of sociology at Colorado College.*

Our project

We conducted site visits to nine undergraduate physics departments. Five of those graduate a high percentage of female majors[1]—typically about 40%—and four graduate a percentage of female majors near the national average—typically 15–19%. We designated the first type as "successful," and the second as "typical." In other respects, we chose schools that were as diverse as possible: some public, some private, some religious, some secular, some liberal-arts based, some small universities, some predominantly white, some historically black. The schools also varied significantly in cost and selectivity.

Two or three female physicists from our eight person team (members are listed in the box on page 51) spent two full days on each campus. We interviewed male and female faculty and students, the department chair, and the academic dean responsible for natural sciences. We observed classes and labs and toured the departments. The youngest of us (Foster, BA in physics, class of 2001) interviewed all of the students. We felt that students would be more candid talking to a contemporary.

While we were working on this project, friends and colleagues would frequently ask, "What have you found out?" They were expecting a quick answer and a couple of silver bullets that would transform a male-dominated department into one in which women thrive. What we found was very different, more akin to many small threads that interweave to form a friendly and inclusive department culture. We developed the weaving metaphor, pictured in figure 2, to portray the different elements in a successful department: The loom itself represents institutional support for the faculty; the faculty form the warp, long taut threads that support the fabric and provide continuity; and the student culture weaves itself onto the structure like the weft of the fabric.

The loom: Recruiting diverse faculty

> We are different individuals and we do things differently but we know how to work together to get things done . . . . We have different interests, we have different personalities, we have different teaching styles, so there is a bit of diversity in this very tiny department. (Male professor)

The most effective departmental cultures found at successful schools fit this professor's characterization. Working as a team does not mean that everyone must be the same and contribute equally to everything. Rather, faculty should recognize and respect each others' strengths, weaknesses, and approaches to teaching. Those differing styles and strengths can combine to create a rich and dynamic department.

> It would be nice to see some really good female professors who are supportive of females going through the science program, just to know that you can get somewhere. (Female student)

This student explains clearly why female role models are so important for other women. Elizabeth Tidball, a pro-

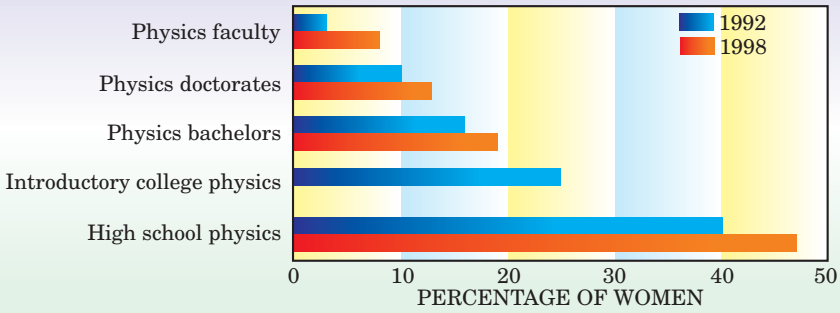

Figure 1. A "leaky pipeline" describes the declining percentages of women who participate at the various levels of physics education. College years account for the largest loss of women from the physics community. (Data for 1992 are adapted from the article in PHYSICS TODAY by Mary Fehrs and Roman Czujko, August 1992, page 33. Data for 1998 are adapted from ref. 1.)

fessor of physiology at George Washington University, has shown that the presence of female faculty is strongly correlated with the number of female students who become scientists.[6] Seeing how different women with different family situations arrange their lives helps newer female students see how they might balance a career in science with a satisfying personal life. And there are some issues that female students are reluctant to raise with even the most sympathetic male adviser.

However, despite their influence, female faculty are not absolutely essential for a female-friendly department. Three of our five successful schools had an all-male faculty. Clearly, men can be very effective mentors and supporters of female students; faculty need not wait to hire a woman to make their department female-friendly in other ways.

Family-friendly policies

To bolster their appeal, departments can take steps to attract talented women. Family issues typically are a critical part of the career decisions female faculty make. Sue Rosser, dean of Ivan Allen College at the Georgia Institute of Technology and former chief of women's programs at NSF, and E. O'Neil Lane, of the Georgia Tech Research Corp, interviewed female NSF-grant recipients about the most significant career challenges facing female scientists today.[7] By far the most common response, occurring more than twice as often as any other, was "balancing work with family responsibilities (children, elderly relatives, etc.)."

Yet at every school we visited, including the successful ones, deans and department chairs seemed unaware of any connection between family policies and the recruiting of female faculty. Although a department may want diversity in its faculty ranks, a person's dilemma of choosing a job where his or her partner also has good prospects is often viewed as simply a burden couples have to work out on their own. The issue does make it hard for colleges to hire new faculty, especially women. A full complement of family-friendly policies, shown in the table on page 48, will support different kinds of families at different life stages.

None of the schools we visited had all of the listed family-friendly policies in place. College administrations often resist such policies because they are too expensive. But failed searches are expensive, too, as is losing a new faculty member after spending money for startup equipment. Losses of a new hire are costly to faculty morale as well. We visited departments in which the faculty were exhausted and demoralized by search after failed search, and were making do with inexperienced temporary teachers. In one small, isolated department, the faculty seemed almost in shock because of the sudden and unexpected departure of a dynamic professor whose wife had found a job elsewhere. The costs of family-friendly policies need to be balanced by the benefits of recruiting and retaining a dynamic, diverse, and committed faculty. In that respect, educational institutions lag far behind the marketplace.

> [Professor——] is a person who is genuinely concerned and loving toward students, but he'll worry you to death—you know how your mom is always bugging you? That's [him]. He'll

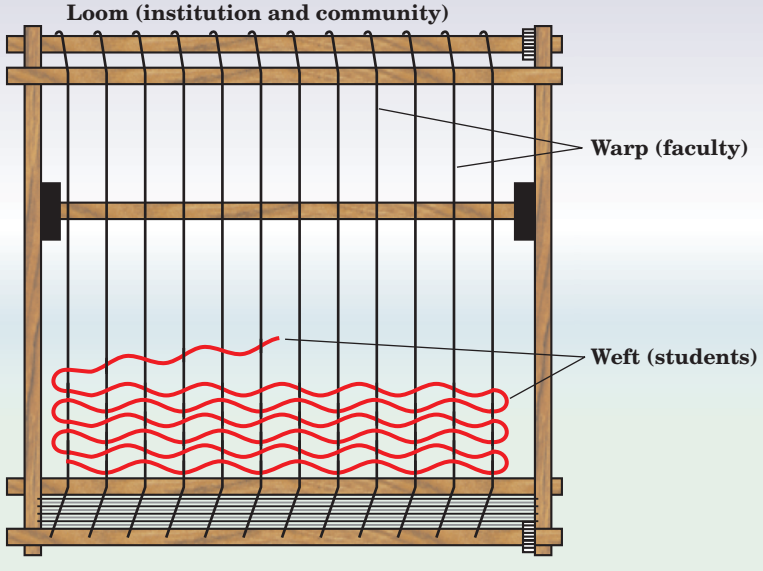

Figure 2. Departmental culture as woven fabric. Faculty, students, and the community combine to create a supportive environment.

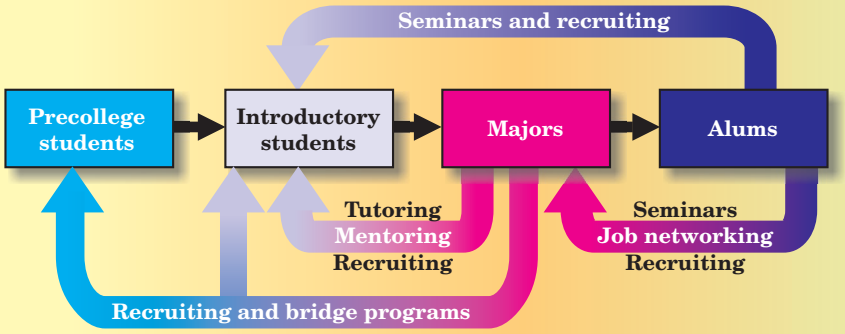

Figure 3. Students create the weft of an inclusive, female-friendly department culture. Successful schools create a network of support systems that extends beyond their current majors in both directions, to introductory students, precollege students, and alums.

> call you every day if he has something on his mind—drives me batty. (Female student)

Institutional support for personal lives is healthy for students as well as faculty. In an atmosphere of excessive devotion to students, faculty can become overly parental. That annoys students. More important, it deprives them of responsibility. Faculty who prefer to spend time in their offices can be poor role models for students, particularly students who are wondering how they might combine their interest in physics with their desire for a family. A warm and active department culture is an important part of a female-friendly department, but it should not supersede commitments to family and friends outside the department. Margaret Eisenhart, professor in the school of education at the University of Colorado at Boulder, and Elizabeth Finkel, a science teacher at Noble High School, a public school in Maine, argue that fields like physics are "greedy," demanding too much time and energy, and driving away women who would like a rich and satisfying personal life in addition to their career.[8]

The warp: The introductory course

> How many times can you sit there and solve problems like "how fast is the block sliding down the incline?" . . . If you took physics in high school it was a lot of the same stuff. (Male student)

Each school we visited follows a traditional approach to the curriculum, even at the introductory level. That accords with the results of the SPIN-UP project (Strategic Programs for Innovations in Undergraduate Physics—see Bob Hilborn and Ruth Howes's article on page 38), which also found a remarkable uniformity in the physics-major curriculum. Our conversations with students suggest that faculty should consider more innovative subjects and interactive pedagogy in the introductory course. Both male and female students frequently described the traditional introductory course as boring and repetitive of high-school physics. Cookbook labs that emphasize error analysis rather than concept development received poor student reviews. Students spoke highly of open-ended, project-based labs, even if they were more time-consuming than traditional labs. Courses designed for nonmajors (astronomy and conceptual-physics classes, for instance) also received more positive reviews.

> [The physics course for elementary education majors included] a lot more examples and demos and real life situations—a lot less math. Things that anyone would be interested in knowing, like Bernoulli's principle is when the shower curtain comes in on you and sticks to you. . . . General stuff that makes physics fun, especially for people who don't like math. (Female student)

The former elementary education student quoted here chose the physics major after taking the nonmajors physics education course she describes. And she is not alone—we heard several cite a nonmajors introduction, approached from an innovative format, as a reason for the decision to major in physics. Faculty often feel freer to be exploratory and innovative in such courses than in the calculus-based course for majors—the pressure to cover content appears to inhibit experimentation.

Beyond the anecdotal level, validating the effect of innovation on teaching success has proved difficult. The uniformity in the traditional approach adopted in all of the departments we visited prevented us from making any strong correlations. Interestingly, however, in the few cases of nontraditional courses we found, women seemed more likely than men to experiment with innovative or interactive teaching formats.

Four-year mentoring

> As a freshman coming in and not having a lot of experience with the department, I wish they would do something to make the individual professors seem more approachable when you first start off. (Female student)

Essential Family-Friendly Policies

Solutions to the "two-body problem"	Institutions can encourage both the hiring of faculty partners and networking with other institutions. Laurie McNeil and Marc Sher offer recommendations for couples and schools (see their article in PHYSICS TODAY, July 1999, page 32).
Generous and inclusive family leave	Family leave policies should be designed for different kinds of families at different stages of life. Administrators should ensure that employees will not face repercussions for taking family leave.
Childcare	Childcare should be offered on-site and be partially subsidized. Coordination of school breaks with public school vacations may help working parents.
Family-friendly atmosphere	In such an environment, faculty children are welcome in the department: Administrators should be tolerant of family demands on the faculty.

Warming up the department

Here are important threads in a student-oriented culture.

Provide a student lounge. This area gives students a place to study together, tutor other students, and interact socially. Departments with a comfortable lounge have markedly improved student relations. Faculty drop by to chat with students, which prompts casual interactions (see figure 5).

Offer a tutorial service. This service has many benefits: Newer students get another resource beyond sometimes intimidating professors; older students get a job that lets them practice explaining physics concepts. Students feel at home in the student lounge if sessions take place there. And perhaps most important, students in more advanced classes automatically become mentors to less experienced students.

Use student lab assistants. Students in more advanced classes may advise those in the introductory classes, thus providing the same benefits as a tutorial service. An added benefit: Physics majors gain valuable experience in setting up equipment and trouble-shooting problems.

Schedule departmental seminars. Use these sessions to focus on undergraduate interests—jobs or postgraduate opportunities, for example.

Create a Society of Physics Students chapter or other physics club. These clubs provide opportunities for social interactions, physics-related activities, and career counseling. Some successful departments have one club meeting specifically devoted to the concerns of introductory students.

Here are important elements that can foster a female-friendly culture.

Monitor the student culture. Make it clear that sexist and racist remarks and behavior are unprofessional and have no place in a laboratory or classroom.

Foster a cooperative spirit. Rather than create a competitive atmosphere in the department, encourage cooperation in class, from formal group activities to informal study groups.

Mention female and minority scientists. For example, emphasize Nobel laureates and leaders in the field to students in class or on departmental posters. Highlighting a variety of physicists may help women and minority students feel more strongly tied into the physics community.

Emphasize applications to environmental and social issues. Elaine Seymour and Nancy Hewitt found that women and minorities often choose careers in science for societal reasons.[3]

Encourage student–faculty research. Such research is an important part of an undergraduate education in science and can facilitate a less formal relationship with professors.

Ensure that students feel safe working in the department alone or at night. Of the female students we interviewed, none expressed concern over their safety. We include the caveat simply as a critical aspect of helping students feel comfortable in the department.

Sometimes, faculty don't really know how they strike students, even in departments like the ones we sampled—small, undergraduate-oriented, and focused on teaching. Faculty frequently say that they have an open-door policy, that students feel free to come in anytime to talk about classes, plans, or personal matters. But our interviews indicate that's not always the student perception at typical departments. Physics majors complained that, in their first year, they did not receive the open-door policy message the faculty thought they were sending. The problem vanishes in upper-level classes that are small and informal, when students get to know the faculty and their fellow students well. But in the introductory classes, special efforts on the part of faculty to approach students—potential majors, especially—are often lacking.

At one successful school, the professor teaching the introductory class identifies potential majors and regularly invites them to departmental activities. The day we visited he was handing out tickets for a trip to see Michael Frayn's play *Copenhagen*. Some departments designate a particularly good teacher who is also good at recruiting. One successful department teaches an introductory class specifically for physics majors, to avoid exposing less experienced, serious students to more experienced and possibly intimidating nonmajors who are less interested in the class. Yet another school designed a discussion-oriented section to appeal to women and minority students. Generally, students at schools without some form of personal attention more often spoke negatively about their first-year course.

The weft: Creating departmental culture

In a successful department, there exists an environment in which everyone is accustomed to working together: More experienced students guide less experienced ones, and faculty members act as role models, cooperating as a team and supporting each other in their professional and personal lives. The faculty can provide a comfortable, stable network of support for a healthy student body. Figure 3 illustrates the departmental connections.

Some of the threads of a warm, student-friendly department culture are given in the box above. It is important to ensure that the student culture is not a boys club; some typical departments are so male-dominated that women may feel uncomfortable and out of place. The second part of the box suggests ways for faculty to help create an inclusive student culture.

Students do much of the work to create a warm, friendly, inclusive departmental culture. They staff tutorials and labs, run the physics club, and plan social activities. They work in recruiting and outreach programs and keep in touch with alumni and alumnae. These activities lighten faculty loads and give students a sense of belonging and responsibility.

Outreach

At successful schools, recruiting often begins before students even enroll in college. Faculty members judge science fairs, teach in summer bridge programs, and visit local high schools—all high-profile ways to advertise. Departmental Web sites designed to emphasize the participation of women also attract a wide pool of students. If available, the department's telescope or planetarium can be used for outreach at local schools. Current majors effectively assist with such efforts, and our findings suggest it is often female students who are most involved.

Successful departments extend their efforts in another direction as well. Faculty at most undergraduate schools maintain contact with a few alums who have gone on to prestigious graduate schools and academic careers. But at successful schools, the network is more extensive and connected with current students in the department. At two successful schools, the department chairs pointed out photographs of graduating classes and shared stories of alums who had taken various career paths (see figure 4). One chair described with equal enthusiasm a former student who is now a veterinarian and another who is in graduate school in physics at MIT. Posters of research done by present and former students decorated the walls and were pointed out to us with pride.

Figure 4. This Louisiana university's physics department does an unusually good job of keeping in touch with alums and using them to recruit students to graduate schools and jobs. This photo wall of past graduates is prominent in the department office. (Photo courtesy of Matthew F. Ware, Grambling State University.)

> In the physics department, we run a career panel where we bring back graduates from the last 10 or 20 years. And the networking system is displayed there. And some of the students from the '70s and '80s now are division chiefs, so they can offer jobs. They are good role models. We try to balance them in gender too. (Male professor)

At successful schools, faculty members invite alums to give seminars, recruit for graduate school, and provide students a sense of what life as a physics major can be. In a small department without graduate students or postdocs, that extra dimension adds perspective.

Historically black colleges and universities

Among the schools we visited, historically black colleges and universities (HBCUs) were especially effective at creating networks of support. These schools are well-known for producing great numbers of African American scientists.[9] Less well known is their female-friendliness. A recent study of African American female scientists showed that 75% received their bachelor's degrees at HBCUs.[10] Of the 20 schools that graduate the highest percentage of female physics majors in the US, 8 are HBCUs.[1] What accounts for that remarkable record?

The physics departments in the two historically black colleges in our study do many of the same things other successful departments do, and they do them exceptionally well. Faculty members at HBCUs are dedicated to the success of each student. They make strong efforts to recruit students by visiting local high schools and teaching summer bridge programs. They involve students in research and physics-department–related activities from the beginning and they maintain contact with alums, encouraging them to visit, advise inexperienced students, and recruit students to graduate schools and jobs. They also use their own students as tutors, recruiters, and mentors for less experienced students. And all of that is accomplished with minimal resources. The success of such efforts calls into question claims by wealthier schools that a program to improve the learning environment for female students is just too expensive.

> Really you don't start taking a physics class until you take calculus 1. I took elementary functions, which is basically precalc. Then I took calculus 1 and 2, now I'm in calc 3. It really depends on the person coming in. (Male student)

This student describes his starting point in physics and implicitly alludes to the alternative route, in which students with stronger backgrounds jump right away into the more traditional calculus-based introductory course. The matter-of-fact tone of his remarks is as important as the actual words—there is clearly no stigma attached to starting at a lower level.

That attitude is the one important and distinguishing feature common only to the historically black colleges we visited. Their faculty typically distinguish clearly between students who are interested and talented in physics and those who happen to have a good high-school physics background. Background courses in mathematics and physics are offered to prepare anyone with a background insufficient for the calculus-based majors course. The institution and faculty are dedicated to helping students overcome deficiencies in their background without lowering standards.

> [Good faculty members will] cover the content and go the extra mile and give the student the assistance, but they have to hold the student to the standard. They don't lower the standards because the student has a deficiency. Physics is physics wherever you are. (Female dean)

Our hope

A central result of our study is that several factors contribute to making a departmental culture inclusive to a variety of students. Typical departments have some of those threads, but successful departments have more of them. Not surprisingly, when departments make efforts to be more friendly and inclusive, both genders notice the difference. But even though warming up a department benefits all students, it seems to help women in particular. Sociology partly explains the difference: Women tend to value interpersonal relationships more than men. And a sense of isolation may explain another part of the difference: Typical departments simply have many fewer women than men. Perhaps male students can more easily develop peer relationships that help them survive a "cold" department.

Many of our observations are in accord with the findings in the SPIN-UP project discussed on page 38—that is, many small factors combine to create thriving departments. The surprise is that SPIN-UP researchers did not observe a significant increase in women or minority students. We are continuing to study this complex issue, com-

Figure 5. "Build it and they will come." A basic student lounge is often enough to draw students for conversation, brainstorming, tutoring sessions, or between-class snacking. A microwave oven, coffeemaker, and refrigerator are all on the other side of the room. (Photo courtesy of Michael S. Korth, University of Minnesota, Morris.)

paring SPIN-UP data to our own, to understand the differences between thriving departments and female-friendly ones. We also plan to widen our school sampling to include women's colleges and other minority-serving institutions.

Although we studied undergraduate-only physics departments, many of our results may be adapted to larger research-oriented departments that cater mainly to graduate students. To develop a warm, female-friendly culture in these schools, it is important to focus on the first year, before students are fully integrated into the department. Department chairs should choose the undergraduate adviser and the introductory (calculus-based) class instructors carefully; those faculty members should be friendly, accessible people to whom students easily relate. Other useful ways to integrate the department include encouraging graduate students to informally mentor undergraduates and inviting undergraduates to seminars and departmental parties. It may also be useful for the undergraduate adviser or the department chair to meet regularly with women students to discuss any concerns.

Physics departments around the country are making progress, and we hope that trend continues. Some research universities are beginning to see the relationship between family-friendly policies and the recruitment and retention of female faculty, for example. Both Georgia Tech (http://www.advance.gatech.edu/overview.html) and the University of California, Irvine (http://advance.uci.edu/home.html) have included family-friendly policies in their NSF ADVANCE institutional transformation grants. We encourage graduate-student–focused physics departments that are interested in improving their climate for women to contact the CSWP and request a site visit. The program is described on the CSWP Web page (http://www.aps.org/educ/cswp/visits/index.html). Further results for graduate programs are found in references 4 and 5.

This project was funded by the National Science Foundation Program for Gender Equity. The American Physical Society's Committee on the Status of Women in Physics was very supportive, especially Neal Abraham, Judy Franz, Suzanne Otwell, and Alice White. We are grateful to Rachel Ivie and Patrick Mulvey of the American Institute of Physics for providing statistical support. It is a pleasure to acknowledge our colleagues listed in the box above who lent their expertise and time. Finally, we are most grateful to the students and faculty of the departments we visited.

Site visit participants

Patricia E. Allen of Appalachian State University, Boone, North Carolina
Suzanne R. Foster of Colorado College, Colorado Springs (all visits)
Paula R. L. Heron of the University of Washington, Seattle
Laura McCullough of the University of Wisconsin–Stout
Kimberly A. Shaw of Southern Illinois University, Edwardsville
Beverley A. P. Taylor of Miami University, Oxford, Ohio
Barbara L. Whitten of Colorado College (all visits)
Heather M. Zorn of the University of Washington, Seattle

(See reference 11 for a more complete description of the project and its results.)

References

1. R. Ivie, K. Stowe, *Women in Physics, 2000*. AIP pub. no. R-430 (2000). The report is available online at http://www.aip.org/statistics/trends/highlite/women/women.htm.
2. NSF, *Women, Minorities, and Persons With Disabilities in Science and Engineering: 2000*, NSF rep. no. 00-327, Arlington, Va. 2000. Available online at http://www.nsf.gov/sbe/srs/nsf00327.
3. E. Seymour, N. Hewitt, *Talking about Leaving: Why Undergraduates Leave the Sciences*, Westview Press, Boulder, Colo. (1997).
4. M. S. Dresselhaus, J. Franz, B. C. Clark, *Improving the Climate for Women in Physics Departments*, American Physical Society and American Association of Physics Teachers, College Park, Md. (1995).
5. B. L. Whitten, *CSWP Gazette*, Fall 2000, p. 3.
6. M. E. Tidball, *J. Higher Educ.* **57**, 606 (1986).
7. S. V. Rosser, E. O. Lane, *J. Women and Minorities in Sci. and Eng.* **8**, 163 (2002).
8. M. Eisenhart, E. Finkel, *Women's Science: Learning and Succeeding from the Margins*, U. Chicago Press, Chicago, Ill. (1998).
9. W. Pearson Jr, L. C. Pearson, *J. Negro Educ.* **54**, 24 (1985).
10. C. B. Leggon, W. Pearson Jr, *J. Women and Minorities in Sci. and Eng.* **3**, 213 (1997).
11. B. L. Whitten, S. R. Foster, M. L. Duncombe, P. E. Allen, P. R. L. Heron, L. McCullough, K. A. Shaw, B. A. P. Taylor, H. M. Zorn, *J. Women and Minorities in Sci. and Eng.* (in press). ■