Chapter 3

Improving Undergraduate Education in the SBE Sciences

It is not enough that individual faculty members in isolated ways advance student learning. Many . . . have suggested that what we need is not more innovation but more implementation, so that local improvements are both spread throughout the institution and made sustainable over time. Otherwise, gains will be transitory and depend on the comings and goings of individual faculty and administrators.[12]

Current Context

Key Needs

For more than a decade, the social and behavioral sciences, like many fields and disciplines within the arts and sciences, have been engaged in reexamining and reforming undergraduate education. The progress made by groups convened by national professional associations or higher education commissions notwithstanding, there remains substantial need to move beyond "trickle down" knowledge, specific notable initiatives, and institutional symbols of support to structural and institutional change. In 1998, for example, the Boyer Commission on Educating Undergraduates in the Research University called for significant transformations in undergraduate education to make research-based learning the standard. Yet, a survey undertaken three years after the Boyer Report found that only 25 percent of responding universities reported participation in research by at least half of their social science students.

Small colleges and large-scale universities all grapple with the dual purposes of exposing undergraduates to the thoughts, materials, and methods of a discipline or area of inquiry while simultaneously attracting, nurturing, and preparing some of these students to pursue advanced degree training.[13] Particularly in SBE sciences that have very large service courses and train large numbers of undergraduate majors, these goals may seem distinct and difficult to reconcile. Yet, in reality, the very same analytic reasoning and inquiry skills are essential for both advanced

[12] National Science Foundation, *Shaping the Future: New Expectations for Undergraduate Education in Science, Mathematics, Engineering, and Technology* (NSF 96-139) (Arlington, VA: National Science Foundation, 1996), p. 56.

[13] Data indicate that SBE majors do not pursue advanced scientific degrees at the same rate as in the natural and physical sciences or engineering: In 2000, only 4 doctoral degrees were awarded per 100 bachelor's degrees, compared with 9 doctoral degrees for every 100 bachelor's degrees in the other sciences. See National Science Foundation, *Science and Engineering Degrees: 1966-2000* (NSF 02-327) (Arlington, VA: National Science Foundation, 2002).

degree training and strong undergraduate liberal learning.[14] This point was central to reports on arts and sciences majors prepared by 12 disciplines, including economics, political science, psychology, and sociology, as part of a project led by the Association of American Colleges in 1989-1990.[15]

Although the SBE disciplines and fields have pursued a range of strategies to alter education at the baccalaureate level, much remains to be done. In almost every SBE science, explicit recognition of the importance of a sequenced and integrated curriculum, sound methodological training, and research-based experience far outstrips implementation of these objectives. There is also a general awareness that strengthening SBE undergraduate education will require comprehensive faculty development in substantive knowledge, teaching techniques (e.g., active learning), and advising and mentoring. Finally, there is growing recognition of the desirability of rethinking how undergraduate programs in the various SBE sciences relate to each other and align with prior or subsequent education (i.e., K-12 education, two-year college education, and graduate education).

U.S. colleges and universities are quite diverse in terms of their size, structure, mission, and the composition of their student populations. Consonant with this variation, the SBE sciences have an opportunity to advance public literacy in these sciences, to prepare undergraduates for numerous career options, and to enrich the skills and knowledge of those pursuing advanced scientific training in these fields. There are barriers and challenges in doing so, as set forth below, but sustained NSF presence, commitment, and funding can produce meaningful and realistic methods and models of change.

Impediments and Challenges

The gains to be realized from enhancing public awareness and literacy in the SBE sciences and from enlarging the pool of individuals attracted to scientific careers in these fields are enormous.

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[14] In every SBE discipline, there are departments that are successful in educating and training undergraduate students for advanced degrees. Many of these departments, however, still face the challenge of providing majors with skills to enter the labor market. Departments that integrate or offer additional training in research methods and experiences are enhancing students' comprehension of SBE fields as sciences as well as students' job-related skills. Departments with large numbers of majors face particular challenges in meeting these goals.

[15] Each of the social and behavioral science disciplines prepared reports on the undergraduate major under the auspices of task forces convened by their scholarly associations. These reports provide important guidance to departments that seek to mesh the dual objectives of providing strong liberal arts education and the skills and reasoning consonant with developing scientific capacity. See, for example, John C. Wahlke, "Liberal Learning and the Political Science Major: A Report to the Profession," *PS: Political Science and Politics*, March (1991): 48-60, and Paul Eberts, Carla B. Howery, Catherine W. Berheide, Kathleen Crittenden, Robert Davis, Zelda Gamson, Theodore C. Wagenaar, *Liberal Learning and the Sociology Major* (Washington, DC: American Sociological Association, 1990). In 2002, a follow-up Task Force of the American Psychological Association (APA) on Undergraduate Psychology Major Competencies issued a report on the *Undergraduate Psychology Major Learning Goals and Outcomes* that sets forth ten goals and learning outcomes addressed to knowledge, skills, and values consistent with the science and application of psychology and consistent with liberal arts education. See http://www.apa.org/ed/pcue/reports.html.

Among the key impediments to realizing those benefits are:

First is the challenge of designing courses that meet the needs of undergraduate majors, potential majors, and non-majors. The SBE sciences have substantial responsibilities for general education introductory courses and most entering students have little or no background in these fields. This situation requires that courses often serve double or triple purposes. Also, limited cooperation among SBE science departments on matters of substance has been an impediment to collaborating on quality SBE general education for non-majors, whether taught within one SBE department or across several departments.

Second, the absence of well-defined objectives for SBE general education makes it difficult to design and sequence lower-level courses for majors. Better articulation of what constitutes quality SBE general education would enrich SBE education in two-year and four-year colleges and the alignment between the two.

Third, structural differences between two- and four-year colleges and the difficulties students encounter in transferring from the former hamper baccalaureate SBE education in colleges and universities. In the absence of well designed articulation agreements between associate- and baccalaureate-degree conferring institutions, conflicts arise over matters large and small, from the way course credits are counted and calculated, to the definitions of disciplines, and over such broader questions as definitions of the arts, humanities, and sciences.

Fourth, an impediment to curriculum transformation for baccalaureate programs in the SBE sciences is that department faculties too seldom work as groups to craft curricula based on learning objectives and a sequencing of courses that reflect the instructional goals (in concepts and tools) they seek to meet. The inertia of longstanding practices and patterns in academic departments, traditional reward systems that favor individual accomplishment and autonomy, and a lack of information about the processes integral to effective teaching and learning (or indifference to their benefits) will continue to limit change in the absence of intentional commitments to do otherwise.

Fifth, insufficient resources, the absence of institutional signals of support, and pressures on faculty time are real and symbolic impediments to department-wide examination of courses and materials and to the pedagogical changes essential to transforming SBE undergraduate education. At the individual level, there are issues of faculty workload, training, and development. At the department or other institutional level, there are issues of how to make intentional and sustainable change when resources and facilities are often quite limited and faculty—at various career stages, with varying backgrounds, and at different levels of motivation—may need to be convinced that changes are feasible and desirable.

Sixth, the overall absence of an explicit plan for research-based training and mentoring limits the quality of the developmental experience for many SBE majors. Though disciplines vary (with psychology incorporating the most research training), research experiences and mentoring typically derive from one-on-one, ad hoc matches between faculty and students—with little department-level consideration of what research experience should be provided to all majors and with the elements of quality mentoring assumed, rather than examined.

Seventh, the demands on faculty for quality research experiences can vary within and across disciplines, depending on the nature of the research and the research programs of interest to students or being undertaken by faculty. Projects that require intensive fieldwork or the design and development of new research instruments can be far more demanding of faculty training and mentoring time than projects where students join laboratory teams when experiments are underway or where students are using extant databases.

Eighth, SBE departments have put limited emphasis on examining pedagogical strategies in light of education research and cognitive psychology. Knowledge of how students learn, assessment instruments, and performance are seldom used as tools to evaluate students' progress and determine what works. It is difficult to work effectively with students or design sequenced curricula without better knowledge about how to enhance retention of knowledge, improve the integration of knowledge, and promote understanding and combining of concepts.

Ninth, foundations, agencies, and other entities allocate insufficient funds to enhancing undergraduate education in the SBE sciences. College and university faculty members who are motivated to improve SBE education within or beyond their own disciplines have few or no incentives for devoting time and energy to such efforts within current reward structures, and may in fact encounter real disincentives. They are particularly discouraged by reports that NSF enrichment programs for undergraduate science education exclude (or are told to exclude) the SBE sciences.

In sum, the impediments to improving SBE education at the community college and the baccalaureate level are a varying mix of individual, financial, and institutional factors that depend on specific contexts and circumstances. For example, challenges to change may vary by available resources and by the scale of a department—in particular, student-faculty ratio and whether master's or doctoral programs are offered. Nevertheless, because of NSF's strong and historic leadership role in supporting the advancement of the SBE sciences, it is in a unique position to help overcome such challenges and impediments.

Best Practices

Most of the best practices in SBE undergraduate education to date have emphasized research opportunities and research-related activities. The value of such experiences has been tested over many years with support and leadership from SBE science societies and funding agencies (e.g., through NSF's funding of REU supplements and sites). Institutional change at the department level, however, has been slow to occur despite recognition by a number of disciplines of the need to develop integrated and sequenced curricula, to devote greater attention to methods training and research experiences, to utilize active learning techniques, to incorporate quality mentoring, and to provide a broader spectrum of materials. Illustrative best practices making a difference in SBE undergraduate education include:

- Since 1993, the American Sociological Association has led two major initiatives aimed at transforming undergraduate education through department change. The first initiative, Minority Opportunities through School Transformation (MOST), funded by the Ford

Foundation, worked with competitively selected departments on department-wide, sustainable change in terms of curriculum (emphasizing analytic and methodological skills), research training, mentoring, climate, and outreach to enhance the educational experience for *all* students. The second initiative (Integrating Census Data Analysis into the Curriculum), undertaken with National Science Foundation support, works with cohorts of departments and their faculties on the development of scientific reasoning skills by incorporating data analysis throughout the curriculum.

- The Council on Undergraduate Research (CUR) is a national membership organization dedicated to promoting undergraduate research and mentoring. Comprised of 380 institutional members (from primarily undergraduate institutions) and over 3,200 individual members (from more than 900 colleges and universities), CUR has promoted the full integration of the social sciences in all of its activities and programs. Explicitly emphasizing the importance of cross-disciplinary exchange, in 2001 CUR expanded its division structure (which also defines its governing Council) by adding a Social Sciences Division. Previously, a Psychology Division was the only SBE science division.

- The UCLA Student Research Program (SRP), in tandem with the Undergraduate Research Center for Humanities and Social Science, provides opportunities for students' engagement in research under the guidance of mentors. While the vast majority of SRP students major in the physical and life sciences (82 percent of some 2,500 student annually), a sizable number of SBE students are funded each year, and the existence of the Center sends a strong signal of interest and support to SBE students. Course credit (up to four units for 20 hours per week), an SRP contract between student and mentor, and research-stipends for financially eligible students all help encourage research experiences. The Center provides the infrastructure for supportive activities, including sponsorship of a poster day, assistance to departments in featuring their students' work, an undergraduate research website, an archive of collected data, a student journal, and funds to students to defray the costs of travel to present research papers.

- Since 1996, the American Psychological Association (APA) has offered a nine-day Summer Science Institute. With demand for admission far exceeding available places (32 students are selected from about 500 applications), this APA program focuses on rising sophomores and juniors. While short in duration and not the intensive experience that, for example, REU sites provide, the institute stimulates bonds across a national talent pool of psychology majors, exposes them to interactive discussions about scientific inquiry and hands-on laboratory research, and conveys information about career options and graduate training. The APA model illustrates that some gains are possible with limited resources.

Components of an Action Plan

These examples point to some of the ways SBE undergraduate education is being enhanced. While funding has been limited in absolute dollars, the National Science Foundation has played a key role in supporting innovative projects. Increased investments would make a major difference in improving and transforming SBE undergraduate education. Among possible strategies, those

that build on making existing NSF programs explicitly accessible to the SBE sciences offer the quickest results at the least cost. Extant programs within EHR are particularly ripe for SBE applications, and strategies to encourage submissions should be pursued.

Enhanced Funding for Critical SBE and EHR Programs

1. EHR Programs to Diversify the Presence of Underrepresented Minorities in SBE Sciences within the Division for Human Resource Development are appropriate to developing and training a diverse pool of SBE scientists, improving the skills and capacities of the scientific workforce, and strengthening the role of minority-serving institutions. Immediate and significant improvements in SBE undergraduate education would result from participation by SBE faculty and students in existing NSF programs, including:

- LSAMP (Lewis Stokes Alliance for Minority Participation);
- AGEP (Alliance for Graduate Education and the Professorate);
- CREST (Centers of Research Excellence in Science and Technology);
- Historically Black Colleges and Universities Undergraduate Program (HBCU-UP); and
- TCUP (Tribal College Undergraduate Program), among others.

Since many of these programs cut across educational levels, they are considered more fully in the chapter on Diversity in SBE Science Education. These initiatives have valuable consequences for capacity building in doctoral training, and thus the overall absence of funding of the SBE sciences is problematic. For example, LSAMP and AGEP seek to enrich the pool of underrepresented minorities pursuing doctoral study and ultimately research careers in science. Such initiatives are essential to the SBE sciences. Whether SBE scientists are being excluded from these programs or whether they are not applying because they believe they do not qualify, the net effect is the same: Opportunities to improve SBE science education are being missed, and efforts to enhance the skills of SBE scientists are not being nurtured.

2. The NSF Research Experiences for Undergraduates (REU) Program in the SBE Directorate, and in particular the REU site awards, are a critical component of SBE science education and should be substantially expanded. Now typically summer intensive programs (of five to ten weeks in duration), the REU site awards provide sound models for training and education. On issues ranging from experimental psychology and behavioral and cognitive sciences to cultural anthropology and minority group demography, REU projects provide solid coursework, an intensive research experience and mentoring, exposure to research careers, and contacts with a cohort of students engaged in learning about options and opportunities. These projects also enhance the teaching and mentoring skills of participating faculty.

A major increase in funding for the REU program within the SBE Directorate, coupled with explicit efforts to encourage broader participation by SBE disciplines in two-year and four-year colleges and universities, would yield immediate and significant payoffs in improved SBE education. The flexibility of institutions to adapt REU awards to their distinctive needs, specialties, and mores should be maintained, and even expanded. For example, as part of outreach to students not otherwise drawn to research, awards could include partnerships

with academic service learning programs to train students in research skills in the context of community service activities. Awards could be offered at the institutional level (as is now done, but with an additional focus on the academic year and potentially across departments), at the regional level with several institutions engaged in collaboration, or at the national level through leadership and coordination from SBE scientific societies. REU site awards are excellent vehicles for enhancing the participation of students of color in the SBE sciences and in research groups.

3. The Course, Curriculum, and Laboratory Improvement (CCLI) Program in the EHR Division of Undergraduate Education offers a key opportunity for expanded support of the SBE sciences. This program area has funded creative work in these sciences. Whether the emphasis is on instructional innovation (e.g., use of Just-in-Time teaching methods in economics), curriculum development (e.g., a two-course sequence building upon active learning in GIS-science education), or materials development (e.g., using DVD technology for samples of real behavior for classroom use), much can be gained from greater investment in improving SBE undergraduate education. Currently, funding in SBE undergraduate education is very limited in the CCLI tracks, depending on the area, with no or few awards directed to the assessment of student achievement. Expanded funding through EHR could add projects in SBE areas where almost nothing currently exists and be directed to working with investigators to scale up projects, institutionalize change, and help map better strategies for SBE education reforms.

Especially important would be major and sustained allocations for projects that have considerable potential for transportability and implementation within or across SBE disciplines and fields. For example, the current three-year award on Renewing the Undergraduate Curriculum to the Society for American Archaeology, a five-year award for Workshops and Seminars to Improve the Teaching and Learning of Geography in Higher Education, or the previously mentioned three-year award to work with cohorts of sociology departments to integrate data analysis throughout the curriculum all aim to reach large numbers of departments, faculties, and students and to work at national as well as institutional levels. Initiatives of this scope, ambition, and duration can profoundly enhance undergraduate education within and across the SBE sciences.

4. The Science, Technology, Engineering, and Mathematics Expansion (STEP) Program is well suited to meet the challenges of SBE science education. To date, this initiative has not funded projects in the SBE sciences. STEP, however, has considerable potential for expanding the talent pool of individuals (including of persons of color) exposed to scientific work in SBE fields. The SBE sciences face the problem of late declaring majors. The STEP program offers a solution. High school transition projects (e.g., summer bridge projects), programs that establish undergraduate science community centers with developmental experiences for undergraduates (making the transition from Peer Leader to Pathway Scholar), partnership programs with high schools (especially those with at-risk students), partnership programs between two- and four-year institutions, mentor-intensive projects, and peer instruction initiatives that increase student engagement as teachers and learners are all promising avenues to better education in the SBE sciences. While many SBE sciences have large numbers of majors, the STEP program provides a funding framework to enable SBE majors in increasing numbers to become scientists-in-training early in their careers.

New Opportunities and Initiatives

Collaboration of SBE and EHR Directorates on a Systemic Reform of SBE Undergraduate Education. This initiative would encourage proposals that seek to implement long-term sustainable change within SBE departments, across departments, or in interaction with centers. Curriculum reexamination, research-based training and mentoring, and the development of innovative materials and tools could all be features of such proposals. The emphasis would be on model programs that can be tested and transported to other institutions. This initiative should incorporate ongoing interaction among funded projects to share and disseminate information on systemic reform (perhaps by convening an annual grantees meeting). Any disciplinary or interdisciplinary program, department, institute, or school seeking to develop appreciation and comprehension of SBE-related sciences by undergraduates should be eligible to apply. Preparing Future Faculty-type projects could usefully be considered under this initiative as long as their strategies seek to produce institutionalized change.

Collaboration of SBE and EHR Directorates on SBE Educational Innovation. Similar to the Educational Innovation Program in the Computer and Information Science and Engineering Directorate, this program would seek to improve the undergraduate learning experience by infusing research results and advances into courses and curricula. This initiative would aim to strengthen the content of courses with current research (including attention to the tools and methods used to produce it). Projects that engage active researchers in collaborating on course redesign and teaching and that link enhanced research-based courses with actual research experiences for undergraduates could be given priority. Projects directed to the development of education standards in disciplines, interdisciplinary fields, or across fields, led by teams, working groups, or scientific associations could be supported under this initiative.

Collaboration of SBE and EHR Directorates on Undergraduate Faculty Enhancement. This initiative would provide support to institutions (scientific societies; the Inter-university Consortium for Political and Social Research; consortia of two-year colleges, four-year colleges, and universities) to design and offer workshops, mini-courses, and extended institutes to new faculty and to experienced faculty members wanting to retool their pedagogy or methods as they relate to courses or to guiding students in research-based experiences. Student involvement in the design of such projects could usefully enhance the fit between teaching and learning. Faculty taking such training would receive support as part of this initiative.

Immediate Steps

- Publicize the program announcement for the NSF Director's Award for Distinguished Teaching Scholars (DTS) through outreach to SBE scientific societies and to grantees from SBE fields in the SBE and EHR Directorates. Encourage nominations of individuals notable for their significant scholarship and their commitment to teaching. The impact on many different audiences of seeing that such awards are conferred on SBE scientists cannot be underestimated.

- Convene a workshop of REU site grantees and SBE-CCLI grantees from fiscal years 2001-2003 to present their innovations (e.g., process, progress, pitfalls); identify commonalities in terms of course, curriculum, and educational practices; and consider strengths, gaps, next steps, and strategies for dissemination and diffusion. Include non-grantees from across the SBE disciplines and fields, including in research areas where there are not separately designated SBE programs (e.g., demography, education research, child development). Ensure a dissemination plan to make known promising practices and transportable approaches for improving SBE science education.

- Request that the National Research Council's (NRC) Committee on Undergraduate Science Education explicitly include SBE sciences in future workshops and reports as well as in the composition of the committee. Commission a panel review, convene a workshop, or fund a brief supplement (e.g., to the Social Science Research Council or to this NRC Committee, possibly in collaboration with DBASSE) to examine the NRC reports on undergraduate education in terms of the applicability of their contents and recommendations for SBE undergraduate education. These reports are *Transforming Undergraduate Education in Science, Mathematics, and Technology* (1999); *Evaluating and Improving Undergraduate Teaching in Science, Technology, Engineering, and Mathematics* (2003); and *Improving Undergraduate Instruction in Science, Technology, Engineering, and Mathematics* (2003).

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