

Feature From the National Science Foundation

Transforming Undergraduate Biology Education for All Students: An Action Plan for the Twenty-First Century

Terry Woodin,* Diane Smith,[†] and Deborah Allen*[‡]

*National Science Foundation, Arlington, VA 22230; and [†]University of Montana, Missoula, MT 59812

On July 15–17, 2009, 544 biology faculty from 2- and 4-year colleges and universities, along with researchers, administrators, students, and other educational stakeholders from around the country, met in Washington, DC, to help create a blueprint for the future of undergraduate biology education (Summers, 2009). Hosted by the American Association for the Advancement of Science (AAAS), with support from the National Science Foundation (NSF), the meeting set out to mobilize the nation's undergraduate biology educators to ensure that the biology they teach in their classrooms reflects the biology they practice in the lab and field, and that all students—majors and nonmajors alike—gain a better understanding of the nature of science and the natural world (Mervis, 2009). The charge for the meeting (*Transforming Undergraduate Education in Biology: Mobilizing the Community for Change*) noted that the need for change reflects the radical changes in the science itself as well as the knowledge we are gaining about how people learn and the best ways to ensure that learning takes place. The meeting concentrated on how people have effected change, the results when they did so, and how the attendees and their colleagues could most effectively incorporate this knowledge and understanding into their own approaches to undergraduate education in biology. Videos, slides, and other materials from the meeting are posted at the conference website (AAAS, 2009a). A culminating summary publication is anticipated in spring 2010.

The conference's theme and format were developed through a year-long series of Vision and Change conversations held at sites across the country with biologists from a variety of backgrounds. Seven of the conversations were between faculty members and administrators, one was with professional society representatives, and 13 were with undergraduate students (AAAS, 2009b). Conference activities included small group discussions to draw up the blueprint for the future; a panel discussion to explore mechanisms for

institutional change; plenary talks from Bruce Alberts¹ and James Collins;² additional talks and a panel discussion by other leaders in the field; a presentation by potential funders on resources available to support change efforts; and poster sessions where attendees shared examples of creative curricula, effective assessments, and new approaches that can serve as models for others (AAAS, 2009c).

The small group discussions built on eight themes arising from the prior conversations and the experiences of the conferees (AAAS, 2009d). These themes were as follows: 1) overarching and unifying key concepts and competencies; 2) student-centered learning (engaging students in discourse); 3) assessing student learning; 4) innovations in integrating scientific research experiences across the curriculum; 5) toolkits to support the change; 6) preparing faculty (developing teaching skills and interests of future and current faculty); 7) implementing innovations and assessing their impact; and 8) changing institutional approaches. Participants worked to better define the changes needed, to cite effective efforts to implement these changes, and to discuss next steps each of them and their colleagues could take. Ideas discussed included taking biology out of the realm of the abstract and relating it to the real world, introducing undergraduate student laboratories centered on students conducting original research, and using assessments to improve teaching and learning. For example, one breakout group, facilitated by Peter Bruns,³ worked on identifying various online tools readily available to undergraduate biology educators. This toolkit group recommended that a searchable Google-like database be developed that includes a recommendation function similar to that used by Amazon, a vetting process similar to that of *Consumer Reports*, and an annotation function mimicking Wikipedia. Such a biology education database, which the toolkit group dubbed "Boogle," could make a significant contribution to providing access to the materi-

¹ Bruce Alberts is Editor-in-Chief of *Science* and Professor at the University of California, San Francisco.

² James Collins is Assistant Director for Biological Sciences at the National Science Foundation and professor at Arizona State University.

³ Peter Bruns is Vice-President for Grants and Special Programs at the Howard Hughes Medical Institute.

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[‡] On leave of absence from the University of Delaware, Newark, DE 19716.

Address correspondence to: Terry Woodin (twoodin@nsf.gov).

als faculty need to implement the ideas and recommendations discussed during the meeting. Preliminary conclusions of each breakout group are available on the conference website (AAAS, 2009d).

The first morning of the meeting featured a panel discussion entitled “Transforming Biology Education in the Academy—Creating Cultural Change,” moderated by Alice Huang.⁴ The group of administrators and faculty involved represented a variety of institutions.⁵ They related how their own institutions had approached creation of an institutional culture that encouraged transformation of undergraduate education and noted that if faculty hope to effect change on a large scale (departmental or college-wide), they need to engage their administration and align their efforts with the institutional mission. William Wood cited the effects of the Science Education Initiative at the University of Colorado, Boulder (AAAS, 2009e; additional panel talks available as links to the conference agenda at www.visionandchange.org/index.php/agenda/), a program in which departments use Science Teaching Fellows as agents of change. The fellows are postdoctoral students with a strong doctorate degree in the departmental discipline who are interested in the scholarship of teaching within that discipline (Wieman, 2007). These postdoctoral fellows work with departmental faculty to develop learning goals, classroom activities to help students achieve them, and assessments to monitor the results. Departments compete for institutional support funds from this program by demonstrating the depth of their commitment to change in undergraduate education. Currently, five research-intensive science departments, including the Physiology Department, are engaged in this program. Since 2006, this 5-year program has affected approximately 10,000 students each year. Although specific learning outcomes are still being documented, 53 courses have been impacted and 83% of participating faculty report that the program has had a positive impact on their department. Because of the widespread support for the changes achieved, it seems that the Science Education Initiative will be sustained by the departments at the end of the 5-year developmental period.

The plenary speakers each emphasized why change is so critical to the future of science education and the nation, noting that although faculty do a good job in introducing new biological discoveries, they find it difficult to help students understand the nature of these advances and the nature of scientific discovery. James Collins posed the challenge “Does the Biology You Teach Reflect the Biology You Do” (AAAS, 2009f), whereas Bruce Alberts, in a video presentation (AAAS, 2009g), noted that students learn how to identify the 12 parts of the cell on a multiple-choice test but that they often lack a basic understanding of the scientific

process. He emphasized that course work in the sciences should be designed so that by the time they graduate, all students understand the nature of science and how it is different from other ways of knowing the world, and be able to 1) know, use, and interpret scientific explanations of the natural world; 2) generate and evaluate scientific evidence and explanations; 3) understand the nature and development of scientific knowledge; and 4) have opportunities to participate productively in scientific practices and discourse (National Academy of Sciences, 2006).

Funding agencies pointed to several existing grant programs available to support the kinds of changes in undergraduate biology education discussed during the meeting (AAAS, 2009h). For example, Peter Bruns reported on a newly instituted Howard Hughes Medical Institute (HHMI) program offering institutions the opportunity to engage students, through introductory biology laboratories, to cutting-edge research early in their academic career (HHMI, 2009a). He also cited the numerous web-based resources HHMI has created (HHMI, 2009b). Clifton Poodry⁶ referred conference attendees to the Institutional Research and Academic Career Development Awards, a National Institutes of Health (NIH) MORE program designed to help postdoctoral students develop teaching skills and knowledge as they work with established faculty in minority-serving institutions (NIH, 2009). Linda Slakey⁷ and James Collins noted that such NSF programs as the Course, Curriculum and Laboratory Improvement Program (NSF, 2009a) and the STEM Talent Expansion Program (NSF, 2008), both managed by the Division of Undergraduate Education (DUE) in the Directorate for Education and Human Resources, offer institutions, departments, and individual faculty members the opportunity to apply for support of efforts to institute the sort of changes in biology undergraduate education that were raised at the conference. Furthermore, the Undergraduate Biology Education track of the Research Coordination Networks in Biological Sciences program (NSF, 2009b), jointly managed by DUE and the Division of Biological Infrastructure in the Directorate for the Biological Sciences, offers groups of faculty exploring similar educational approaches the opportunity to establish virtual and actual workshops, conferences, and websites to support exchange of ideas and information.

Working group leaders are now collaborating with the meeting coauthors, Carol Brewer⁸ and Alan Leshner,⁹ to develop a blueprint for wide implementation of the ideas and recommendations generated; the resultant report will be published in early 2010. A Facebook page (Facebook, 2009) has been established to facilitate ongoing exchange of information between conference participants and other interested individuals who share the goal of transforming biology edu-

⁴ Alice Huang is President-Elect of AAAS and Senior Faculty Associate in Biology, California Institute of Technology.

⁵ John K. Haynes is Dean of the Division of Science and Mathematics at Morehouse College; Elaine A. Johnson is Director of Bio-Link at the City College of San Francisco; Joan F. Lorden is Provost and Vice Chancellor of Academic Affairs at University of North Carolina Charlotte; Muriel E. Poston is Dean of Faculty and Professor at Skidmore College; and William B. Wood is Distinguished Professor at the University of Colorado, Boulder, and Editor-in-Chief of *CBE—Life Sciences Education*.

⁶ Clifton Poodry is Director of the Division of Minority Opportunities in Research, National Institute of General Medical Sciences, National Institutes of Health.

⁷ Linda Slakey is Director of the Division of Undergraduate Education at the National Science Foundation and Professor Emeritus at the University of Massachusetts, Amherst.

⁸ Carol Brewer is Associate Dean of the College of Arts and Sciences, University of Montana and Associate Editor of *Conservation Biology*.

⁹ Alan Leshner is the Chief Executive Officer of the American Association for the Advancement of Science and Executive Publisher of *Science*.

cation so that the biology we teach “better represents the biology we do” (AAAS, 2009a).

How will we know whether the meeting was a success beyond the 3 days immediately after the conference, and the conference dates themselves? We will know this meeting accomplished its aims if

- The attendees go back to their institutions and actually recruit other faculty and their institutional administrators to address the issues instead of just planning to do so.
- Students enrolled in biology are participating in exciting courses that help them understand the basic concepts of biology and how they are deduced, instead of just memorizing the facts.
- Assessment instruments are produced that help students and faculty to realize how deeply students understand (or misunderstand) the basics of the discipline, rather than testing for recall of facts or repetition of memorized procedures.
- Web- and print-based tools are available to students and faculty to help them access and interact with the information and tools they need to gain understanding and to become part of a scientific community.
- All citizens understand what the science of biology encompasses, and how it questions the world and finds answers to those questions.

Clearly, it will take years to measure progress toward these ambitious goals, but meanwhile the issuance of the proceedings of the conference should help provide pathways to follow, and indicate milestones to monitor our progress.

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