Vision and Change in Undergraduate Biology Education: Preliminary Reports of Conversations

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CONTENTS

ABOUT VISION AND CHANGE IN UNDERGRADUATE BIOLOGY EDUCATION: A VIEW FOR THE 21ST CENTURY

Over the past year, the American Association for the Advancement of Science (AAAS) with support from the National Science Foundation (NSF) held a series of conversations with faculty, administrators, students, and other stakeholders on the future of undergraduate biology education. To put the conversations in context, the following provides a brief overview of why these conversations were initiated, the current efforts by funding agencies to meet the needs identified by these conversations, and the hoped for outcomes of these and subsequent conversations.

The Need

Both the disciplines of biology and of science education have undergone a revolution. The major focus of the biological sciences – understanding life – remains unchanged, but breakthrough discoveries of the second half of the 20th century have changed the basic nature of the questions asked, while new and emerging technologies are changing the ways key questions are addressed. In undergraduate science education, new approaches and new technologies are also emerging based on evolving theories of learning. New developments in higher education have changed the manner in which people pursue higher education, and there is also a growing appreciation of the need to broaden participation within the sciences by advancing the education of all students, including those from underrepresented groups and those who will enter careers outside of science.

There is also a growing realization of the necessity to fully inform and educate all students about the wealth of professions available to those who study the sciences and about the way science is done. BIO2010 helped rouse interest in the need for reform of undergraduate biology education raising many important issues and giving suggested approaches, mostly applied to those students preparing for a career in biomedical research. This program could serve as a base for a broader approach that would encompass all the sub-disciplines within the biological sciences.

Current Efforts

Most of the current efforts to support needed changes in undergraduate biology education are centered either at the National Science Foundation (NSF) or the Howard Hughes Medical Institute (HHMI). Pertinent efforts at NSF include the support of materials development, changes in course delivery, and efforts in faculty development through the Course, Curricular and Laboratory Improvement Program managed by the Division of Undergraduate Education. Other relevant programs include the Career Program managed by the Directorate for the Biological Sciences and other research directorates at NSF. The HHMI programs are by invitation only but serve a variety of institutions in their efforts to respond to the forces for change. For example, HHMI supports summer institutes at the University of Wisconsin focused on faculty change at research institutions and those with large introductory courses. In addition the National Institutes of Health (NIH) has initiated a program, Institutional Research and Academic Career Development Awards (IRACDA) to involve postdoctoral students in educational change.

Hoped for Outcomes

The overarching goal of the on-going conversations has been to provide a forum where the biology community can gain insight into the changes that need to take place, how best to effect those changes, and how

best to support efforts for change. As a culmination of these conversations, a conference will be held in Washington, DC on July 15-17, 2009. At this meeting, those currently involved in reform will exchange information about what they are doing, network across the various sub-communities within biology (e.g., emerging fields such as systems biology, bioinformatics, and proteomics as well as traditional fields such as molecular, biochemical, ecological, organismal, physiological, evolutionary, botanical, zoological, microbial, etc.), devise mechanisms to improve coordination, and raise the visibility and degree of adaptation of such efforts. The meeting will result in a printed report and action plan for improving the quality of undergraduate biology education, as well as an online resource where stakeholders can share information and access specific resources to implement the ideas and strategies developed at the conference.

ABOUT THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

The American Association for the Advancement of Science (AAAS) is the world's largest general scientific society and publisher of the journals, *Science* (www.sciencemag.org) and *Science Signaling* (www.sciencesignaling.org). *Science Translational Medicine* (www.sciencetranslationalmedicine.org) will be published beginning in the fall 2009.

AAAS was founded in 1848, and serves 262 affiliated societies and academies of science, reaching 10 million individuals. *Science* has the largest paid circulation of any peer-reviewed general science journal in the world, with an estimated total readership of 1 million.

The nonprofit AAAS (www.aaas.org) is open to all and fulfills its mission to "advance science and serve society" through initiatives in science policy; international programs; science education; and more.

For the largest research news, log onto EurekAlert!, www.eurekalert.org, the premier science-news Web site, a service of AAAS.

AAAS has four primary program areas, including Education and Human Resources, International Activities, Project 2061, and Science Policy.

Visit the AAAS website at www.aaas.org.

QUESTIONS TO GUIDE FACULTY "CONVERSATIONS"

In 2008, the American association for the Advancement of Science , with support from the National Science Foundation, sponsored a series of conversations with faculty, administrators, students, biological sciences professional societies and other stakeholders including the Howard Hughes Medical Institute and the National Institutes of Health on the future of undergraduate biology education. The following questions were used to guide these conversations.

What should be the main goals of the 21st century undergraduate life science curriculum, and how do these goals translate into desired outcomes?

1. Outcome Goals for Biology Graduates
    a. What professional and technical knowledge should be expected of graduates in the life sciences? What are the "core" concepts in our discipline?
    b. What other skills and knowledge will be required for graduates in the life sciences, given their likely career choices and societal needs (e.g., critical thinking skills, leadership skills, public policy, civic engagement, global understanding)?
    c. How do we attract and engage the broadest range of talent to the life sciences?
    d. How can formal education be better integrated with informal and lifelong learning by life science graduates?

2. Outcome Goals for General Education in the Life Sciences for All Students
    a. Given the personal and societal challenges that students will face in the future, what knowledge and skills from the life sciences are important for all college graduates?
    b. How can we best ensure that graduates from our colleges, universities and community colleges are prepared to be lifelong learners in the life sciences?

How do we design a curriculum to achieve these goals, and what is the best way to deliver that curriculum?

3. Curricula, Laboratories, Pedagogy, and Learning Technologies
    a. What experiences can we provide to best prepare students for their future working environment?
    b. What can we do to help students who are underprepared?
    c. Given the explosion of information in the life sciences, how can we construct a curriculum that balances depth within one's subdiscipline with the need for breadth and integration?
    d. How do we balance disciplinary depth with the increasingly interdisciplinary nature of the problems confronting life scientists?
    e. How can we best incorporate active learning strategies (and other "best practices") into the life sciences curriculum at all levels and for all students?

f. What is the role of undergraduate research, internships, and service learning in the life sciences curriculum?

g. Given the rapidity of change in the life sciences, how do we keep the curriculum current?

h. How do we best integrate into the life sciences curriculum the basic knowledge and tools that students need from other disciplines (e.g., math, chemistry, physics, earth sciences, etc.)?

i. How can we best gather and evaluate evidence on what works and what doesn't work?

4. Faculty, Departments, and Institutions

a. How do we better prepare current and future faculty for their role as teachers, guides, and mentors? How do we build a culture that values continued improvement in teaching and learning?

b. How do we overcome the barriers to departmental and institutional evolution and change? What strategies are effective in breaking down disciplinary "silos"?

c. Do we need to change and can we change the faculty reward and tenure system?

d. How can we best handle the special challenges facing community colleges and their faculty? What can we do to aid students in the transition from two-year to four-year programs?

e. What needs to be done to modernize laboratory and classroom facilities to take advantage of new learning and research technologies and best pedagogical practices?

5. External Influences and Constraints on Education in the Life Sciences

a. How can life science education adapt to and engage an increasingly diverse student population?

b. How can undergraduate life science education keep pace with the changes in higher education (e.g., changes in student life, increasing costs of education, decreased funding for higher education, increased demand for accountability, etc.)?

VISION AND CHANGE IN UNDERGRADUATE BIOLOGY EDUCATION: A VIEW FOR THE 21ST CENTURY

2007–2008 Faculty Conversations

Preliminary Report

Organized by the American Association for the Advancement of Science
with Support from the National Science Foundation
Division of Undergraduate Education and Directorate for Biological Sciences

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INTRODUCTION

Both the disciplines of biology and of science education have undergone a revolution. The major focus of the biological sciences – understanding life – remains unchanged; but breakthrough discoveries of the second half of the 20th century have changed the basic nature of the questions asked, while new and emerging technologies are changing the ways key questions are addressed. In undergraduate STEM education new approaches and new technologies are also emerging based on evolving theories of learning. New developments in the nature of institutions of higher education have changed the manner in which people pursue higher education, and there is a growing appreciation of the need to broaden participation within the sciences by advancing the education of all students including those from underrepresented groups and those who will enter careers other than those related to science. There is also a growing realization of the necessity to fully inform and educate all students about the wealth of professions available to those who study the sciences and about the way science is done (Vision and Change briefing document, 2007).

To determine how undergraduate biology education can best reflect the exciting recent advances in the biological sciences and the knowledge gained about teaching and learning, the American Association for the Advancement of Science (AAAS) organized "Vision and Change in Undergraduate Biology Education: A View for the 21st Century," a set of informal conversations designed to enable a wide segment of the biological sciences community to explore the changes that need to take place and how best to effect those changes. A key outcome of the project is the development and expansion of effective networking and coordination among the stakeholders in this change process, as well as raising the overall visibility of the change process among stakeholders, policy makers, and the general public.

This report summarizes ideas collected in 2007-2008 through a series of seven "conversations" on undergraduate biology education conducted at locations throughout the United States. The conversations engaged 180 participants, a majority of them biology faculty, administrators, and others actively engaged in the discipline and in teaching biology. Participants represented almost all the sub-disciplines within biology, a wide variety of academic institutions and a variety of experiences ranging from post-docs to those well established in their field. In addition to the conversations, 80 representatives from professional societies were invited to a meeting organized by the American Institute of Biological Sciences (AIBS) and AAAS to discuss their perspectives on undergraduate education in the biological sciences. The conversations included, as observers and in other roles as appropriate, representatives of AAAS and NSF. In addition, some conversations included representatives from the Howard Hughes Medical Institute (HHMI) and the National Institutes of Health's National Institute of General Medical Sciences (NIGMS), Division of Minority Opportunities in Research (MORE).

Each conversation was informed by a paper summarizing the issues prompting the need for the discussion and a series of background questions to help frame the discussions. Participants were first asked to frame a question of importance to them and indicate why it was important to consider this issue. The participants then regrouped to agree on key points for discussion in the afternoon, which centered on resolving issues raised in the morning. Summaries of comments from across the conversations are provided below.

CURRICULUM

A. Focus on Two Major Goals

The curriculum should focus on two major goals: 1) Engage students in the process of science; and 2) Present science as a vibrant and active field. To engage students in the scientific process, they should have:

- Hands-on laboratory/field experiences within courses;
- Research opportunities in laboratories/field;
- Inquiry-based activities allowing active exploration of a broad theme or model system; and
- Manipulation of large and small data sets, with use of spreadsheets and data analysis to develop quantitative skills.

Students should perceive biology as an evidence-based science with testable theories and data to support them and should clearly understand "…how scientists know what they know."

Students should see biology as a growing and dynamic field that applies the scientific method to global problems. Toward this end, the curriculum should link the content knowledge students learn to policy and advocacy issues and opportunities. Students should also see biology as a human endeavor, engaging real people in important investigations. Undergraduate biology clubs could be launched to offer students opportunities to participate in biology activities outside the classroom and to network with biologists in informal settings. Finally, students should understand that biologists form a worldwide community, collaborating on research and teaching. There should be expanded opportunities for biology students to do international studies during their undergraduate years.

B. Build an Active-Learning Curriculum

The 21st century biology curriculum should be rich with active-learning opportunities. Content coverage must be carefully selected to provide time for students to engage in active-learning activities. A balance must be created between content knowledge and process skills development. This is important for both biology majors and students in general education courses, including pre-service elementary teachers who will introduce students to their first science lessons.

Research experiences should be incorporated for all students via research laboratories or inquiry-rich laboratory courses. Institutions should create tools to help students locate research opportunities; these could include lab-matching services, seminars on finding a research lab, or undergraduate biology clubs. Institutions or professional societies could publish student research, for example, on their websites to further hone and reinforce the importance of writing and research skills.

Integrate skills development throughout the curriculum. Quantitative skills and writing skills development should be embedded within the biology curriculum as well as taught in mathematics and/or English/writing courses. Students should be able to identify problems, develop hypotheses, structure explorations, carry out data collection and data analysis, and draw appropriate conclusions from the data. Students should develop written and oral communications skills to allow them to develop constructive arguments based on evidence, collaborate with partners, work as teams, and share their findings. Finally, students should be able to determine the accuracy and validity of information and its sources, distinguish between real science and unsupported claims in print and web-based sources, and assess the real level of controversy on a subject.

Finally, the curriculum should utilize technologies that engage student interest and interaction. Examples include on-demand audiovisual content (webcasts/podcasts) and social networking websites (e.g., Facebook, MySpace, etc.).

C. Keep Content Current

Textbooks, by their nature, cannot reflect the most current content in science. They tend to reinforce students' perception of biology as a compendium of facts rather than a dynamic and ever-changing body of knowledge. Therefore, curriculum should not rely on textbooks as the sole source of information for students. Course content should link curricular activities to real-world problems and science-in-the-news stories that are socially relevant to the target audience of students. It should also link the curriculum to the primary literature, wherever possible, and integrate research seminars as course activities.

D. Structure Curriculum to Address Student Needs

It is critical to recognize that the diversity of biology students and their needs are greater than ever. Several groups are still profoundly underrepresented among life scientists, and departments must seek and implement effective methods to recruit, retain, and promote achievement among students of color. Some students come underprepared for the rigors of quantitative study in biology. Those students need more than the standard coursework and may need study skills training to succeed. And an increasing number of students will come to biology education while working full-time to support themselves and their families. These students need additional flexibility in terms of timelines and course structure (e.g., online courses). In addition, an increasing number of students will begin their biology studies as a second career. All of these students, as well as the more traditional students, bring a background of existing knowledge and life experiences. Biology educators must find ways to build connections between students' existing knowledge and experiences and the science curriculum. Finally, many students will begin their undergraduate training at community colleges and seek to transfer to four-year colleges and universities. Connections between and alignment with these institutions must be strengthened to facilitate these transfers.

STUDENT ASSESSMENT AND PEDAGOGY EVALUATION

A. Assess Both Content and Process Objectives

Assessments must match the course objectives and overall learning goals for biology majors as well as for students majoring in other subjects. Therefore, assessments must measure process skills and student perceptions, as well as content knowledge. They should tap into a variety of learning styles and preferences and,

where possible, facilitate further learning rather than simply serving as a final measurement. By going beyond traditional methods, faculty will have a richer set of data by which they can assess student achievement. Student perceptions such as attitudes, perceived learning, levels of engagement, and perceived usefulness can be of great assistance not only in assessing student development but in evaluating course activities. Case studies not only tap content knowledge but process, writing, and teamwork skills. Class activities and assignments such as laboratory reports, electronic homework, clicker questions, and "two-step" tests provide a broader view of a student's engagement and development. Even student discussions on social networking sites can provide insights into student understanding.

Finally, departments should consider having students maintain a portfolio of their work across their undergraduate years. This portfolio provides a venue for student reflections and a powerful set of data for discussions with the student's advisor.

B. Evaluate New Teaching Methods for Effectiveness

Both traditional and new teaching methods have advocates, yet there may or may not be evidence to document their effectiveness. As new methods are incorporated into the curriculum, it will be important to determine which methods have evidence of success and which need evaluation. This should apply to both traditional and new methods. However, this may require assistance from biology teaching scholars, educational researchers, and/or statisticians, particularly when developing an evaluation or testing plan for new materials or methods.

RECOMMENDATIONS FOR FACULTY, DEPARTMENTAL, AND INSTITUTION DEVELOPMENT

A. Build a Culture for Teaching and Learning

Departments and institutions must actively build a culture that supports the scholarship of teaching and learning. Evaluation and assessment data can be used to demonstrate to both faculty and administration that improved teaching and learning using active-learning strategies contribute to achievement of departmental and institutional goals. Biology teaching scholarship must be valued by the institution in order to succeed; therefore, indicators of teaching scholarship should be included as criteria for hiring, tenure and promotion. New faculty should receive start-up funds and release time for teaching as well as research activities. To provide additional expertise for departmental change, institutions should consider hiring science education specialists; these specialists should be well-supported in tenure-track positions in biology departments (or jointly with education departments).

B. Leverage Resources

Departments with similar goals for building a culture for teaching and learning should create partnerships across the institution. By planning together, departments can expedite evaluation planning and, through hiring and training, can develop a "critical mass" of science teaching scholars within and across departments. Finally, successes should be shared; departments should publicize their teaching successes, giving credit to the institution as well as funding agencies.

C. Develop Graduate/Postdoctoral Students as Biology Teaching Scholars

Graduate programs should establish the expectation that their program graduates will have expertise in teaching and teaching scholarship as well as in research. Programs should provide both formal training and ongoing mentoring to develop teaching expertise for both content and process objectives. Where possible, departments should explore opportunities to link research activities and teaching activities. Partnerships should be established or expanded to build cooperative programs between community colleges and research institutions to share teaching mentoring and research opportunities. Finally, these program changes should be evaluated to determine their impacts on graduates' successes in their first professional positions.

D. Develop Faculty as Biology Teaching Scholars

Departments must adopt a clear definition of the scholarship of biology teaching so that faculty members understand their target goal. This definition should be incorporated in the development of criteria for new faculty hires. Departments should provide both structured training and ongoing mentoring to develop teaching skills for both content and process skills. Where possible, existing programs of demonstrated effectiveness should be replicated rather than creating new programs. Finally, departments should recognize the importance of adjunct faculty and include them in faculty development initiatives.

E. Provide Institutional Recognition and Rewards

Teaching scholarship must be recognized as an important contribution to the department and institution, not a "dead-end" career choice. Release time should be provided for faculty development and development of teaching materials and methods. Finally, biology teaching scholarship must count positively in tenure and promotion decisions.

RECOMMENDATIONS TO DEVELOP NATIONAL RESOURCES

A. Work toward Developing a Consensus on a "Common Core," and Explore Life Sciences Accreditation and National Assessments

Participants voiced support for the development of an overarching set of core concepts and competencies and hoped that a set of standardized assessment instruments could be developed to aid in determining student attainment of learning goals. The possibility of an informal accreditation process for life sciences programs was also discussed. Efforts should be undertaken to develop agreement on a common core of topics that should be part of life sciences undergraduate education. This "core" could help guide institutional program revision and development of tools for assessing overall impact. However, there was concern about using such a core and assessments as rigid accreditation benchmarks.

B. Establish a National Center for Undergraduate Education

A centralized center should be created to promote the development of undergraduate education by providing models, training, and support for individuals and departments working to improve their biology/life sciences programs and courses. It would also serve as a center for disseminating programs of demonstrated effectiveness.

C. Establish a National Clearinghouse for Undergraduate Education Materials and Pedagogy

There was strong support for creating an online national clearinghouse for life sciences/biology teaching materials and strategies. This could be done by an expansion or revision of BioSciEd Net (BEN), the National Science Digital Library's Pathway Portal to the Life Sciences, or through another portal such as Merlot or Nature Education. A registry of "best practices" and "best materials" should be a part of the national clearinghouse, as well as links to data sets for teaching quantitative skills and summaries of research on teaching and learning.

RECOMMENDATIONS FOR PROFESSIONAL SOCIETIES

The conversations resulted in a recurring call for professional scientific societies to play a greater role in improving undergraduate life sciences education. Recommendations ranged from providing materials and training for educators to promoting the importance of scholarship in teaching and learning. Major recommendations are summarized below.

A. Set a New Standard

Professional societies should set a new standard for how their members view the scholarship of teaching and learning. This should occur through their normal activities (meetings, publications, awards). Peer-reviewed science education journals and/or articles indicate that the society values educational scholarship and can help faculty seeking tenure based on biology teaching scholarship. Professional meetings should be rich with opportunities to attend sessions on teaching and learning as well as "safe places" to talk about educational issues. Society awards for teaching excellence and teaching scholarship raise the status of these activities for all members.

B. Hold Education Conferences

Professional science societies should hold conferences on education, either jointly with education societies or on their own. These meetings would allow sharing of research findings and project evaluations, facilitate network-building, promote collaboration, and offer professional development in teaching. A biannual Gordon conference was suggested to bring together key education representatives from each society to set an agenda for meetings and projects.

C. Serve as Stewards of the Discipline

A number of groups recommended that professional societies serve as the repository of content knowledge, develop and steward educational materials, and develop and provide professional development activities for their discipline. They should also play a lead role in establishing core content/content inventories for their disciplines. These inventories could ultimately lead to certification of teachers and/or courses as meeting current standards in a subdiscipline. As major publishers of research papers, societies should take the lead in repurposing this content for use by undergraduate students and faculty (e.g., research summaries, PowerPoint slides associated with research articles, etc.). The societies should establish networks of biology educators and provide professional development for both faculty and graduate students.

D. Provide Memberships for Educators

Many biology teachers no longer belong to their professional science society and need mechanisms that would encourage them to use society resources. Special rates on meeting registration and membership, and free access to general content would encourage educators to remain connected to their disciplinary society and utilize its resources in their courses.

E. Collaborate with Other Societies

Scientific societies should work together to implement many of these cross-cutting strategies. Especially important is the need for collaboration related to developing a consensus regarding a common core of "big ideas in biology" that should be included in undergraduate biology.

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Marsha L. Matyas serves as the Director of Education Programs for the American Physiological Society (APS). Her research fields include factors affecting science and engineering interests and participation rates among women and minorities at the precollege, undergraduate, and graduate levels and curriculum development for biology education and professional development. She earned her master's degree in cell biology and her doctorate in science education at Purdue University. For eight years, she directed the Projects on Women in Science at the American Association for the Advancement of Science (AAAS) and served as a program officer at the National Science Foundation.

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In addition, Malcom serves as a Regent of Morgan State University and as a trustee of Caltech. She has chaired a number of national committees addressing education reform and access to scientific and technical education, careers and literacy. Malcom is a former trustee of the Carnegie Corporation of New York. She is a fellow of AAAS and the American Academy of Arts and Sciences. She served on the National Science Board, the policymaking body of the National Science Foundation from 1994 to 1998; and from 1994-2001 she served on the President's Committee of Advisors on Science and Technology.

Malcom received her doctorate in ecology from The Pennsylvania State University; master's degree in zoology from the University of California, Los Angeles; and bachelor's degree with distinction in zoology from the University of Washington. She also holds 15 honorary degrees. In 2003 Malcom received the Public Welfare Medal of the National Academy of Sciences, the highest award given by the Academy.

VISION AND CHANGE IN UNDERGRADUATE BIOLOGY EDUCATION: A VIEW FOR THE 21ST CENTURY
Student Conversations
Preliminary Report

Organized by the American Association for the Advancement of Science
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During the 2007-2008 national Conversations on Undergraduate Biology Education, faculty and others indicated the need to directly engage students in further Vision and Change efforts. As both learners and potential future members of the STEM workforce, students are key stakeholders with a direct investment in the effectiveness of undergraduate biology education.

In response to the need for student perspectives, a "mini-conversation" was piloted at NSF in August 2008 with a small group of undergraduates finishing their summer internships at NSF. Using this conversation as a model, participants in the national Conversations on Undergraduate Biology Education were invited to hold a student mini-conversation on their campus during the spring of 2009. The following is a summary of both the NSF and campus-based conversations, including data about the participants and a summary of student responses.

A. Summary Data on Conversation Participants

Conversations were held at the following 13 institutions: Bates College, The City College of New York – CUNY, Ohio State University, Tennessee State University, University of Massachusetts – Boston, University of North Carolina – Charlotte, University of Akron, University of Chicago, University of Colorado – Boulder, University of Maryland – College Park, University of Nebraska – Lincoln, University of Tennessee – Knoxville, and the University of Washington (two conversations).

The conversations included 231 students, with majors as follows: Biological sciences = 99, other STEM fields = 71 (19 disciplines represented), Humanities = 34 (12 disciplines represented), Arts = 6 (5 disciplines represented), Undeclared = 21.

B. Summary of Student Responses

Professors and biologists care about biology, but why should the rest of us care?

- Biology can connect many topics, both within STEM and more broadly – "biology is life"
- Innovation in other fields often depends on biology
- Everyone needs some knowledge of biology in order to make informed decisions as adults — about health, nutrition, the environment, conservation, "green" living, etc.
- Biology can teach problem-solving skills and an understanding of the scientific method in general; everyone should understand what does and doesn't constitute evidence for a claim

- Biology can help make connections between self and society
- "Facts are at our fingertips" – biology can help illustrate the context and connections
- Biology presents a good way to communicate about science, because many biology topics are immediately relevant and relatable to anyone's life
- An understanding of biology can make people feel more engaged with the earth and its environment and more inclined to take steps to protect it
- Good biology education is needed for global competitiveness
- Biology education is needed to provide solutions for diminishing resources/sustainability issues
- Since many non-majors take biology as their required lab science course, it's a gateway to get more students interested in science

In what ways are we making progress?

- Labs done well can force us to apply what we've learned and this is where the concepts really stick
- Peer-assisted learning groups are a great experience for both the leaders and the attendees
- In some upper level classes, we have been expected to design our own experiments and this is really engaging
- We've had more small group work and investigation of problems with real-world relevance
- There are more opportunities to get involved in research as undergrads (e.g., REU)
- There are more programs that increase the diversity of students in science
- Early biology courses gave students the confidence to ask and answer new questions
- Most programs require some science so more students are exposed to it
- Stories relevant to biology are often in the news, so that emphasizes the importance of studying biology
- Tutors are more widely available and the stigma of having one is fading
- Lab equipment and other technology has become less expensive, so students have had more chances to use it
- Science is more visible in pop culture (e.g., TV shows like CSI, House, Mythbusters, etc.)
- An effort has been made on some campuses to integrate some topics across the whole curriculum
- More learning materials are available online

In what ways can biology education be improved? (Issues and recommended solutions)

"Old school" lecture style is frustrating and not engaging

Recommended solutions and strategies:

- Professors should ask open-ended questions where they don't know the answer – so you are defending your answer and not guessing what the professor wants
- More opportunities for small group work and chances for discussion (e.g., peer teaching/learning), especially in large-enrollment courses
- Incorporate demonstrations or media (e.g. , YouTube) to illustrate topics
- Use quizzes during or after each lecture (e.g. , with clickers) to keep students engaged and see what they did or didn't learn

- The information presented should be appropriate for both visual and auditory learners – just putting all the lecture text onto a PowerPoint isn't very effective

Introductory courses are too broad

Recommended solutions and strategies:

- Give entering Bio 101 students a diagnostic test, and split students into three groups: the ones who really need more basics to supplement what they didn't get in high school, the ones ready for 101, and the ones ready for something more advanced. Stop the "one size fits all" Bio 101
- Reduce the amount of information in classes; teach students how to learn so they can gain depth on their own
- Have more topic-based or concept-oriented courses, especially for non-majors

Less emphasis on memorization

Recommended solutions and strategies:

- More emphasis on application and problem-solving — if science changes so much why are we trying to memorize everything?
- More emphasis on the "how" of science: what is the evidence and how did we obtain it?
- Have projects where knowledge needs to be applied instead of exams where facts are regurgitated
- More essay questions on exams: even in classes where broader concepts are discussed, students are still tested on the fine details
- Use case studies where the professor facilitates a discussion about them

More connections across the curriculum

Recommended solutions and strategies:

- Professors should be more explicit about what they want students to get out of the course and why it's necessary to know those things
- More connections between lecture and lab components within an individual course
- More connections across the disciplines (e.g., between chemistry, physics, and biology)
- More standardization across different sections of the same course
- There should be greater discussion of the curriculum as a whole with the students — why you need this course, that technique, etc., and how it all fits together. Have a short seminar course before or with introductory biology for those who know they want to be biology majors
- More interdisciplinary courses

"Canned" labs are ineffective/uninteresting

Recommended solutions and strategies:

- Have more inquiry-based labs where the answer isn't known ahead of time
- Let the students engage in more troubleshooting (instead of the TAs) so they understand why something did or didn't work

- More opportunities for creativity, like letting students design their own lab experiments, especially early on and not just in upper-level courses
- Learn how to work with real data — learn to deal with ambiguity and that science can be "messy"

Courses feel disconnected from "real-world" science: more relevance/context needed

Recommended solutions and strategies:

- Incorporate more discussion about how biology impacts our lives
- Read more primary literature and recent developments — what's going on in the field right now?
- Learn to critically analyze the current literature
- Biology majors should take a history/philosophy of science or a science-and-society course
- Have topic-based courses designed around real-world relevant issues

Career development resources are lacking

Recommended solutions and strategies:

- The career center should have more resources for those who don't want to go to medical school. Students are getting more interested in interdisciplinary careers and applying biology to other fields, but information about those careers can be hard to find
- Provide an introductory level seminar-style course on "what can you do with a biology degree?" that highlights different career opportunities
- Advisors should be more aware of current opportunities and how to help students find information about potential careers

Better mentoring is needed

Recommended solutions and strategies:

- More chances to find mentors besides just the academic advisor, whose time can be stretched thin
- More organized system for peer mentoring, such as pairing underclassmen with upperclassmen in the same major for guidance

More chances to do research and/or learn how research is done

Recommended solutions and strategies:

- Attendance at research seminars should be required or extra credit
- Research experience in a professor's lab should be a required part of the curriculum; make these research experiences easier to find/access
- Offer a course on experimental design and/or research methods
- The campus brings in outside researchers to talk about what they do, but we don't know about the research in our own departments — have faculty lead seminars on their own work
- Offer workshops for students who want to explore different lab techniques in more detail

- Have a "shadow a professor for a day" activity where students learn how a research lab works

More opportunities/interactions outside the classroom

Recommended solutions and strategies:

- Greater encouragement of outside learning through group study, student affairs groups, discussions, etc.
- More organized opportunities for students to engage in volunteer activities or outreach to the community; let them be role models for K-12 students (e.g. ,working with science fairs or with summer programs for high school students)
- More study-abroad programs that are tailored for biology students: learn how science is done in other countries
- Broaden the memberships in biology clubs — get more non-biologists involved
- Use Facebook or other social networking sites to help create communities of students interested in similar topics

Teaching doesn't seem valued

Recommended solutions and strategies:

- Students don't feel empowered to expect good teaching — the professors care more about their research. Increase the expectation of excellence in teaching — all professors should be familiar with educational theory and there should be more professional development for faculty to enhance their teaching skills. Maybe pair new faculty with more experienced faculty who have demonstrated good teaching skills.
- Instead of professors blaming the students for poor performance, encourage them to look at what they could do differently.
- More value on teaching the intro courses — students seem to get the least-interested professors. Offer some incentives for teaching these courses.
- More avenues for student feedback — professors need to be attuned to what students want out of the class, what they feel they are missing, and students need to feel that they have a voice.
- There should be more 'face-time' with faculty (office hours or small discussion groups).
- Sites like 'ratemyprofessor' are popular with students, but not always embraced by campuses and often a venue for student complaints; maybe a more organized effort could be made to get all students to give and share feedback on courses so students can make more informed decisions and so faculty can see that student opinions are important and hold weight.

More opportunities to develop quantitative skills

Recommended solutions and strategies:

- Offer more courses on quantitative abilities including statistics, programming/computer science, technology, etc., tailored for biology students

More opportunities to develop communication skills

Recommended solutions and strategies:

- More writing assignments in class and/or seminar courses on writing
- More student presentations with chances for feedback

Less emphasis on competition

Recommended solutions and strategies:

- Students feel that there is too much pressure to make "good grades" to get into graduate and professional programs. They are discouraged from trying new and different courses for fear of harming their GPA. Allow four "stretching your mind" courses – where at the end of the course students can opt out of having their course grade reported.

How can we continue to include students in the "Vision and Change" effort?

While only a handful of conversations had time to address this question, several facilitators commented that the students felt honored that their input was being sought by such a large-scale effort and that their perspectives would be shared with a diverse group of educators from all over the country.

- More focus groups like this one
- Provide feedback and updates including how these student conversations guided the effort
- Organize a student conference to discuss issues in biology education
- Create a website or discussion board to allow students to interact and receive updates
- Send surveys to students to get their input on issues that arise

ABOUT THE AUTHOR

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Fry 's experiences with teaching and mentoring deepened her commitment to strengthening science education, prompting her to become more broadly involved in education efforts after completing her doctoral studies. While a AAAS Fellow at NSF, she has collected and analyzed data on the scope and impact of projects supported by the Course, Curriculum, and Laboratory Improvement (CCLI) program, designed and published a series of widely distributed documents to disseminate information about the division's programs to a variety of audiences, and been an active member of two working groups organizing national initiatives aimed at advancing and improving undergraduate STEM education.

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VISION AND CHANGE: PERSPECTIVES AND PROPOSED ACTIONS FROM SCIENTIFIC SOCIETIES

Invitational Summit on Undergraduate Biology: The Role of Disciplinary Societies

November 19-21, 2008

Howard Hughes Medical Institute, Bethesda, MD

Marsha Lakes Matyas, American Physiological Society, Bethesda, MD

INTRODUCTION

In November 2008, the American Association for the Advancement of Science (AAAS), with funding support from the National Science Foundation (NSF) and with the cooperation and participation of the Howard Hughes Medical Institute (HHMI) and the National Institutes of Health (NIH), convened a meeting of professional society leaders to discuss the Vision and Change process. The meeting, "Invitational Summit on Undergraduate Biology: The Role of Disciplinary Societies," invited the leadership of 15 biological sciences societies (*Table 1*), to build on the ideas emerging from the earlier Vision and Change conversations.[1] In particular***, the meeting sought to identify what boards and executive officers of key biological sciences societies should do to foster change in undergraduate biological sciences education.*** More specifically, the meeting gathered information on:

- What biological sciences professional societies are already doing to foster change in undergraduate biological sciences education; and
- Additional actions societies could take regarding governance, programs, meetings, communications, journals, and other publications.

Each society team included the current president or president-elect, one or more members of the governing board, and/or a member of the educational section or committee. Most teams included the executive director/ officer of the society. The meeting was structured as a series of large and small working groups where society leaders worked toward a common vision for change and identified strategies that could be adapted individually or collectively. The meeting provided an opportunity to exchange ideas, illustrate the richness of current experiences within societies, and galvanize more informed action within individual societies and collaboratively among societies.

Table 1: Participating Professional Societies and Other Organizations

PROFESSIONAL SOCIETIES: American Association for the Advancement of Science (AAAS) American Institute for Biological Sciences (AIBS) American Physiological Society (APS) American Society for Biochemistry & Molecular Biology (ASBMB) American Society for Cell Biology (ASCB) American Society for Microbiology (ASM) American Society for Plant Biologists (ASPB) Biophysical Society Botanical Society of America (BSA) Ecological Society of America (ESA) Genetics Society of America (GSA)	Society for Integrative and Comparative Biology (SICB) Society for Neuroscience (SFN) Society for the Study of Evolution (SSE) National Association of Biology Teachers (NABT) **OTHER ORGANIZATIONS:** National Academy of Sciences/ National Research Council (NAS/NRC) National Science Foundation (NSF) Howard Hughes Medical Institute (HHMI) National Institutes of Health (NIH) Project Kaleidoscope

CURRENT SOCIETY ROLES AND ACTIVITIES

At the beginning of the meeting, each society discussed its current activities in support of undergraduate education and provided a list of activity types. Subsequent to the meeting, each society reviewed the list and indicated the activities and programs it currently offers. Activities ranged from short-term commitments, such as occasional education editorials in society journals or symposia at annual meetings, to long-term commitments such as peer-reviewed education journals, paid education staff, and annual education conferences. Table 2 summarizes the current activities noted by the societies.

All of the disciplinary societies have an education committee or board that oversees or provides input on its education activities (Table 1); NABT, as an association of science teachers, has multiple committees focused on education activities. Most (67%) of the participating societies have an education staff of one or more full-time employees. Awards and fellowships that either specifically target or include undergraduate education are common, especially faculty teaching awards (60%), although these are not always exclusively for undergraduate faculty. For students, undergraduate travel awards (67%) were common although fewer societies gave undergraduate research fellowships (40%) or awards for excellence in undergraduate research (33%). Few of the societies gave teaching fellowships to undergraduate students (7%), presented awards for excellence in educational research, or presented awards for mentoring undergraduate students (20%).

Many societies have undergraduate-focused activities at their scientific meetings. All of the participating societies include one or more education sessions at their annual meetings, but there is a wide range in the number and types of sessions. For example, one society schedules an education plenary speaker once every three years while other societies include an education component or focus in nearly all of their sessions and symposia. The majority of the participating societies (60%) find ways to highlight undergraduate research at their meetings, encouraging undergraduate research presentations. Only two of the societies, however, set aside time for undergraduates to give oral presentations or platform talks at their annual meetings. More than half of the societies create structured opportunities for undergraduate students to meet and network at their scientific meetings.

Aside from their scientific or annual meetings, less than half (47%) of the participating societies hold either regular education conferences (such as the ASM Conference for Undergraduate Educators) or ad hoc meetings (such as the APS Undergraduate Brainstorming Summit). Many society representatives expressed interest throughout the meeting in holding regular meetings across the societies to continue the dialogue on undergraduate education.

Finally, many societies exhibit and/or hold workshops at meetings focused on undergraduate research. These included meetings of the Society for the Advancement of Chicanos and Native Americans in Science (SACNAS), Annual Biomedical Research Conference for Minority Students (ABRCMS), and Council for Undergraduate Research (CUR). These meetings offer scientific societies an opportunity to share information on their disciplines, career opportunities, and fellowships with students who have already expressed an interest in research. In addition, societies exhibit at meetings primarily directed toward science educators, including undergraduate faculty in life sciences (e.g., National Science Teachers Association (NSTA) and National Association of Biology Teachers (NABT).

Table 2: Current Activities of Life Science Societies Participating in "Vision and Change" Conference, November 2008

	AAAS	AIBS	APS	ASBMB	ASCB	ASM	ASPB	Biophys. Soc.	BSA	ESA	GSA	SICB	SfN	SSE	NABT
Leadership & Staffing															
Education Committee or Board	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
Paid Education staff	x	x	x	x	x	x	x		x	x			x		
Awards/Fellowships															
Undergraduate faculty teaching award			x	x	x	x	x	x		x	x				x
Undergraduate student research fellowships	x		x		x	x	x			x					
Undergraduate student research awards			x	x					x			x			x
Undergraduate student travel awards	x		x	x	x	x		x	x	x		x	x		
Undergraduate student mentoring award	x		x				x								
Undergraduate teaching fellowships						x									
Undergraduate educational research award															x
Meetings/Meeting Activities															
Include education sessions at scientific meetings	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Highlight undergrad research during scientific meeting	x	x	x	x	x	x			x	x	x				
Schedule undergraduates platform talks during scientific meetings				x		x									
Hold undergraduate student networking sessions at scientific meetings	x		x			x	x		x	x		x	x	x	
Hold separate education conferences or summits	x	x	x	x		x	x								x

Table 2: Current Activities of Life Science Societies Participating in "Vision and Change" Conference, November 2008 *(cont.)*

	AAAS	AIBS	APS	ASBMB	ASCB	ASM	ASPB	Biophys. Soc.	BSA	ESA	GSA	SICB	SfN	SSE	NABT
Exhibit at undergraduate research or teaching meetings (SACNAS, ABRCMS, CUR, NABT)	x	x	x	x	x	x	x	x		x			x	x	
Membership Activities															
Undergraduate membership	x	x	x	x	x	x	x	x	x	x	x	x	x		
Undergraduate chapters on campus		x		x		x				x					
National disciplinary honor society for undergraduates				x											
Online Education Resources															
Digital library (catalogued and searchable)	x	x	x			x			x	x		x			
Online resources (not in digital library)	x	x	x		x	x	x	x	x	x	x		x	x	x
Science presentations online/online lectures	x	x	x		x	x	x			x					
Education website or education web pages	x	x	x	x	x	x	x	x		x	x		x	x	x
Undergraduate student online networking				x			x		x	x					x
Teaching listserv or blog	x	x	x			x				x					
Publications															
Publish peer-reviewed education journal that includes undergraduate education			x		x	x				x					x
Collaborate on joint education journal (e.g., JNRLSE)		x					x			x					
Regular education column in research journal	x	x					x				x				
Occasional education article in research journal		x					x			x	x				
Society newsletter includes articles on education	x		x	x	x	x	x			x			x		x

Table 2: Current Activities of Life Science Societies Participating in "Vision and Change" Conference, November 2008 *(cont.)*

	AAAS	AIBS	APS	ASBMB	ASCB	ASM	ASPB	Biophys. Soc.	BSA	ESA	GSA	SICB	SfN	SSE	NABT
Undergrad research is highlighted in print or online publication	x			x					x	x					
Undergraduate text-book development and/or dissemination							x								
Other Activities															
Internal and external funding sources for undergraduate activities	x	x	x	x	x	x	x		x	x				x	
Formal collaboration on undergraduate activities with other professional societies	x	x	x			x	x		x	x				x	x
K-12 outreach activities	x		x	x	x	x	x		x	x		x	x	x	x
Undergraduate faculty development program	x		x			x	x	x							x
National network of undergraduate degree programs in the society discipline				x											
Curriculum/core concepts recommendations for undergraduate level in the society discipline				x		x	x						x		x
Education foundation to fund activities							x								

Undergraduate students can become members of the large majority of the participating societies, thus encouraging students' affiliation with the field. Similarly, some societies expressed a sense of responsibility for promoting the career development of undergraduate students within their specific scientific discipline. A few societies reach out to undergraduate students on campus, creating disciplinary chapters that hold regular meetings (27%). ASBMB developed a national honor society for students in biochemistry and molecular biology.

Providing teaching and content resources online was one of the most common activities for the disciplinary societies. Nearly all of the participating societies (87%) provide teaching resources and/or science content through their web pages and have an education website. Nearly half of the societies organize their resources as a formal digital library, especially those societies involved in the BioSciEdNet (BEN) collaborative (www.biosciednet.org). The BEN collaborative is a digital portal providing access to 25+ collections of peer-reviewed life sciences resources, primarily from scientific societies. Many societies noted that their online resources include scientific presentations or online lectures (47%).

Online tools also provide ways for students and educators to interact, but only five of the participating societies have a teaching listserv or blog for faculty to discuss education issues. For example, APS has an active Teaching Section listserv that includes participants from all of its subdisciplinary Sections (cardiovascular, renal, etc.). Although many of the participating societies have a site on Facebook, none of the societies indicated that they had a specific social networking site for undergraduate students.

All of the participating societies publish one or more journals; however, only 33% publish a peer-reviewed education journal that includes studies on undergraduate education. Although ASPB does not publish an independent journal, it has participated in a collaborative journal, the *Journal of Natural Resources and Life Sciences Education* (www.jnrlse.org). Several organizations (27%) have a regular education article/section in their scientific journal. For example, AAAS's journal, *Science*, has a regular education section. Other societies (27%) said their scientific journals may have occasional education articles and most (60%) said their newsletters contain education articles. Only four societies indicated that undergraduate research is regularly highlighted in their research publications and only one society is involved in developing or disseminating undergraduate textbooks.

Participants described a number of other important undergraduate activities. Most of the participating societies (67%) solicit and receive external grant support for undergraduate activities to supplement society funds. It also is common for societies to collaborate with other societies on undergraduate activities (60%); e.g., many are involved in the BEN collaborative digital library portal. Not surprisingly, most societies (80%) have K-12 outreach programs that help promote undergraduate science majors to pre-college students.

Less than half of the societies have undergraduate faculty development programs, although many integrate faculty development into their regular scientific meeting activities. ASBMB maintains communication with undergraduate faculty through a national network of undergraduate degree programs in their discipline. Finally, a third of the societies have developed undergraduate curriculum/core concept recommendations for their discipline.

Small Group Discussions

After hearing from all societies about their current activities, the meeting participants discussed undergraduate education in a series of small group sessions. Sessions were structured based on scientific discipline and the role of the participants in their respective societies (that is, presidents, board members, executive directors, etc.):

Session 1: Cross-disciplinary, mixed responsibility

Session 2: Cross-disciplinary, similar responsibility

Session 3: Individual disciplines (e.g., individual society meetings with all representatives)

The small group discussions contributed to the plans of each society but the specific content of the discussions was not included in this analysis.

Planned Society Activities

On the final day of the Summit, each society briefly presented the goals, strategies and next steps that their team planned to bring to the larger membership. Societies were encouraged to replicate successful strategies they heard about in the initial society presentations and to propose new strategies and collaborations. Table 3 summarizes their planned activities. Overall, the planned actions addressed six major goals:

1. Raise the visibility and importance of teaching among researchers in the field
2. Increase undergraduate student affiliation with, and understanding of, the field
3. Develop the 21st century curriculum
4. Prepare faculty to teach the 21st century curriculum
5. Provide online resources for curriculum and professional development
6. Promote collaboration among stakeholders

Each of these is discussed briefly below.

Raise the visibility and importance of teaching among researchers in the field: Society representatives felt that making education activities more visible and more prestigious within the society can increase their impact within departments and give greater credence to individual members' education activities. Therefore, several societies plan to increase the number and/or type of education presentations at their scientific meetings and/or add regular education articles to their research publications. Also, they plan to establish new awards for undergraduate faculty to recognize excellence and/or innovation in teaching.

Increase undergraduate student affiliation with, and understanding of, the field: Some societies want to expand the societies' interactions with, and support of, undergraduate students, by offering undergraduate

memberships and expanding undergraduate activities at their annual meetings. Biophysical Society, which hopes to increase the visibility of biophysics as a major among undergraduate students, will focus on creating more biophysics courses and majors at undergraduate institutions.

Develop the 21st century curriculum: Many participating societies recognized the critical role they can play in establishing standards for core curriculum skills and concepts for their discipline. Several plan to pursue this idea, but would like to collaborate with other societies in this process, share strategies for development, and learn what has already been developed. They also want to develop undergraduate curricular materials that emphasize major concepts, principles and processes, and the experimental basis of knowledge.

Prepare faculty to teach the 21st century curriculum: Although few societies have current professional development programs for undergraduate faculty, many are interested in increasing their activities in this area. Not only did they want to provide professional development for current faculty, but they also are planning programs to mentor the next generation of science educators (postdocs and graduate students). ASBMB indicated that they will explore an accreditation process for demonstrating use of effective teaching methods.

Provide online resources for curriculum and professional development: Not surprisingly, this was one of the most consistent themes throughout the conference. Scientific societies typically serve as the repository for and as disseminators of current scientific information in their discipline. Serving the same role for teaching and professional development resources is therefore logical. However, the formats and routes for dissemination of the primary literature online are well established while development, vetting, and systematic dissemination of teaching and professional development resources are in a relative infancy. Some participants intend to select and disseminate the "best" resources via their society website. Others will package materials from diverse sources (journals, podcasts, lectures, etc.) for easy discovery and use by undergraduate faculty or to build online "toolkits" to allow faculty to construct and share their own "packaged" materials. Those with digital libraries will expand the available resources and also build tools to create teaching and learning communities online. Many participants encouraged the expansion or revision of BEN to serve the needs of the diverse societies.

The discussion and comments during the meeting suggest that the specific "needs" have not been clearly defined. Calls for selecting only the "best" teaching materials for dissemination may not take into account the broad needs of the undergraduate faculty. For example, while the principles that allow the selection of adaptations to extreme climates are consistent, faculty in Alaska, Puerto Rico, and Arizona are likely to seek supporting examples, research, and media on organisms and conditions in their own geographic areas. Yet each will look for materials that utilize proven pedagogy and are scientifically accurate. Moreover, they may seek input from fellow faculty who teach similar courses: "Did this work? What type of students did you use it with? How did you adapt it for your course/area? How did you assess content and skills development?" Therefore, the term "best" must be defined, and the varying needs of faculty in different institutions, courses, and geographic regions must be considered. Selecting materials for online distribution, promoting it to undergraduate faculty, getting feedback from faculty on its usefulness, creating learning communities, and deciding whether a discipline-based website/library or a cross-disciplinary library/portal meets the needs of both the society and the undergraduate educator are issues that were discussed but not resolved during the Summit meeting.

Promote collaboration among stakeholders: Toward that end, several societies hoped to work collaboratively on one or more aspects of the Vision and Change process. Proposed collaborations ranged from coordinating cross-disciplinary undergraduate education summits to share program models and plan collaborative activities to developing targeted collaborations among societies in the same subdiscipline. Many participants asked that the undergraduate education summit for professional societies be held on a regular basis (biennially). The conference would bring life science societies together to share progress, resources, models, and evaluation results. One participant noted that, for many societies, their traditional focus has been on supporting graduate student professional development and participation. Efforts to support undergraduate student development will benefit from sharing experiences among societies.

In summary, as a result of participating in the Vision and Change societies meeting, the 15 life sciences organizations planned to develop new activities and programs, continue or expand their existing programs, and/or replicate model programs from other societies. Although there were few "new" models proposed, there was considerable interest in adapting existing models to fit the needs and membership of individual societies and in collaborating with other societies on cross-disciplinary projects such as the development of core competencies and digital portals to high-quality teaching resources.

Table 3: Proposed New Activities of Life Science Societies

New Activities/Topics	#	%
Increase "importance" of education among researchers		
Make awards for undergraduate education and publicize to the scientific research community; recognize and support outstanding undergraduate educators	4	27
Increase number of education sessions at annual meeting and integrate with scientific sessions	3	20
Add a regular education forum or articles to scientific journal	2	13
Allow extra time in scientific presentations to discuss educational outreach activities	1	7
Bring members who specialize in education to the forefront in the society	1	7
Highlight the undergraduate education mission of the society	1	7
Increase student affiliation with the field		
Offer undergraduate membership and/or actively recruit undergraduate members and their mentor faculty	2	13
Increase the number of students majoring in area	1	7
Increase the number of courses offered in area	1	7
Expand undergraduate minority recruitment/retention program	1	7
Expand undergraduate activities at scientific meetings (presentations, networking sessions, etc.)	1	7
Develop the 21st century curriculum		
Develop core skills and concepts for introductory course	5	33
Promote, develop, disseminate undergraduate curriculum that emphasizes major concepts and principles and process skills, and deemphasizes memorization of details	4	27
Meet with other professional societies to share core skills and concepts listings	2	13
Promote undergraduate curriculum that emphasizes the experimental basis of knowledge	1	7
Utilize previous work on core competencies that have been done in other fields	1	7
Prepare faculty to teach the new undergraduate curriculum		
Expand scientific meetings to provide professional development and resources to local undergraduate faculty and interaction with undergraduates	2	13
Use a working group of innovative undergraduate educators within the society as mentors for postdocs, faculty and for curriculum development or core competencies projects	2	13
Offer more and better undergraduate faculty development activities	1	7
Expand current post-doc training program on teaching to include mentoring by experienced undergraduate faculty	1	7
Encourage better mentoring at annual meetings	1	7
Develop an accreditation program to promote effective teaching methods use	1	7

Table 3: Proposed New Activities of Life Science Societies *(cont.)*

New Activities/Topics	#	%
Provide online resources for curriculum & professional development		
Review and expand digital library content, users, and community building tools	5	33
Package online materials (journal articles, teaching resources, etc.) so they can more easily be found and accessed by user; develop online toolboxes rather than textbooks that include teaching and assessment tools, modules, A/V resources, content materials, etc.	5	33
Promote the "best" teaching resources on the society website	1	7
Promote interaction between society technology committees and education committees	1	7
Explore the role of blogs in promoting excellence in education	1	7
Develop education web/web pages	1	7
Support and contribute to a joint portal with other biological sciences societies	1	7
Promote collaboration among stakeholders		
Hold an education summit	2	13
Create a new vision for undergraduate biology via collaborations between research scientists, science educators, and 2- and 4-year college faculty.	1	7
Collaborate with other societies in same subfield	1	7
Bring department chairs and undergraduate program directors together to discuss issues	1	7

Comparison to Undergraduate Faculty Recommendations

The 2007-2008 Vision and Change Conversations with undergraduate faculty provided the background for the Summit with society representatives. Those initial conversations[1] included several recommendations for professional societies (Table 4). With the exception of targeting educators for membership with reduced fees, these recommendations are fully aligned with those made by the society representatives. This suggests that the vision for how societies can support the reformation of undergraduate teaching and learning is shared by both the society leadership and the undergraduate educators who are seeking reform. Therefore, the activities planned by the societies should be well-received by innovative educators and have excellent prospects for long-term implementation and impacts.

Table 4: Faculty Recommendations for Professional Societies

Set a New Standard	Through its normal activities (meetings, publications, awards), societies should set a new standard for how their members view the scholarship of teaching and learning. Peer-reviewed science education journals and/or articles indicate that the society values educational scholarship and can help faculty seeking tenure based on biology teaching scholarship. Professional meetings should be rich with opportunities to attend sessions on teaching and learning as well as "safe places" to talk about educational issues. Society awards for teaching excellence and teaching scholarship raise the status of these activities for all members.
Hold Education Conferences	Societies should hold conferences on education, either jointly with education societies or on their own. These meetings would allow sharing of research findings and project evaluations, facilitate network-building, promote collaboration, and offer professional development in teaching. A biannual Gordon conference was suggested to bring together key education representatives from each society to set an agenda for meetings and projects.
Serve as Stewards of the Discipline	Societies serve as the repository of content knowledge, developer and steward of educational materials, and developer and provider of professional development activities for their discipline. They should play a lead role in establishing core content/content inventories for their disciplines. These inventories could ultimately lead to certification of teachers and/or courses as meeting current standards in a subdiscipline. As major publishers of research papers, societies should take the lead in re-purposing this content for use by undergraduate students and faculty. The societies should establish networks of biology educators and provide professional development for both faculty and graduate students.
Provide Memberships for Educators	Many biology teachers no longer belong to their professional science society and need mechanisms that would encourage them to use society resources. Special rates on meeting registration and membership, and free access to general content would encourage educators to remain connected to their disciplinary society and utilize its resources in their courses.
Collaborate with Other Societies	Societies should work together to implement many of these cross-cutting strategies. Especially important is the need for collaboration related to developing a consensus regarding a common core of "big ideas in biology" that should be included in undergraduate biology.

Comparison to Undergraduate Student Recommendations

In addition to holding conversations with undergraduate faculty from around the country, the Vision and Change project engaged more than 125 undergraduate students at 13 colleges and universities in discussions on biology courses, teaching methods, and recommendations for improving biology education to better engage and educate 21st century students.[1] When asked why all undergraduate students should be interested in biology, participating undergraduates cited the relevance of biology to issues they viewed as critical: personal health, global health and nutrition, environmental issues and conservation, problem-solving skills, understanding the importance of valid scientific evidence for a claim, sustainability and global competitiveness, and developing the next generation of scientists.

When asked whether and how progress was being made in teaching biology to develop interest among all students, most comments cited student-centered pedagogy as the key: peer-assisted learning groups, designing their own experiments, investigating problems with real-world relevance, participating in research experiences, integrating current news items and popular culture (e.g., TV shows "CSI," "House," etc.) into courses, providing online learning experiences, and integrating topics across the whole curriculum.

When asked how biology education could be improved, students cited a number of issues but also offered numerous recommendations for resolving them. Appendix A includes a summary of the issues and recommendations made by students, including the following:

- "Old school" lecture style is frustrating and not engaging
- Introductory courses are too broad
- Less emphasis should be placed on memorization
- More connections across the curriculum are needed
- "Canned" labs are ineffective/uninteresting; inquiry-based labs should be used
- Courses feel disconnected from "real-world" science: more relevance/ context needed
- Career development resources are lacking
- Better mentoring is needed
- More chances should be provided to do research and/or learn how research is done
- More opportunities/interactions outside the classroom should be provided
- Teaching doesn't seem valued
- More opportunities to develop quantitative skills are needed
- More opportunities to develop communication skills are needed
- Less emphasis should be placed on competition

Both the issues and recommendations made by undergraduate students are very consistent with the issues raised during the Vision and Change conversations[1] and the society representative Summit.

[1]Matyas, Marsha Lakes, Yolanda S. George, and Shirley M. Malcom. (2008, October). *Preliminary Report on the "Vision and Change in Biology Undergraduate Education: A View for the 21st Century" Project (Summary of 2007-2008 Conversations).* Washington, DC: AAAS.

Appendix A:

Issues and Recommendations from Undergraduate Student Discussions

Issue	Selected recommended solutions/strategies
"Old school" lecture style is frustrating and not engaging	• Professors should ask open-ended questions where they don't know the answer – so you are defending your answer and not guessing what the professor wants • More opportunities for small group work and chances for discussion (e.g., peer teaching/learning), especially in large-enrollment courses • Incorporate demonstrations or media (e.g., YouTube) to illustrate topics • Use quizzes during or after each lecture (e.g., with clickers) to keep students engaged and see what they did or didn't learn • Information presented should be appropriate for both visual and auditory learners – just putting all the lecture text onto a PowerPoint isn't very effective
Introductory courses are too broad	• Give entering Bio 101 students a diagnostic test, and split them into three groups: the ones who really need more basics to supplement what they didn't get in high school, the ones ready for 101, and the ones ready for something more advanced. Stop the "one size fits all" Bio 101 • Reduce the amount of information in classes; teach students how to learn so they can gain depth on their own • Have more topic-based or concept-oriented courses, especially for non-majors
Less emphasis on memorization	• More emphasis on application and problem-solving. If science changes so much why are we trying to memorize everything? • Emphasize the "how" of science: what's the evidence and how did we obtain it? • Have projects where knowledge needs to be applied instead of exams where facts are regurgitated • More essay questions on exams. Even in classes where we discuss broader concepts, we are still tested on the fine details • Use case studies where the professor facilitates a discussion about them
More connections across the curriculum	• Be more explicit about what students should get out of the course and why it's necessary to know those things • More connections 1) between lecture and lab components within an individual course and 2) across the disciplines (chemistry, physics, and biology) • There should be greater discussion of the curriculum as a whole with the students – why you need this course, that technique, etc., and how it all fits together. Have a short seminar course before or with introductory biology for those who know they want to be biology majors • More interdisciplinary courses

"Canned" labs are ineffective/ uninteresting	• Have more inquiry-based labs where we don't know the answer ahead of time • Let the students engage in more troubleshooting (instead of the TA's) so we understand why something did or didn't work • More opportunities for creativity, like designing our own lab experiments, especially early on and not just in upper-level courses • Learn how to work with real data – learn to deal with ambiguity and that science can be "messy"
Courses feel disconnected from "real-world" science: more relevance/ context needed	• Incorporate more discussion about how biology impacts our lives • Read more primary literature & recent developments. What's going on in the field right now? • Learn to critically analyze the current literature • Biology majors should take a history/philosophy of science or a science-and-society course • Have topic-based courses designed around real-world relevant issues
Career development resources are lacking	• The career center should have more resources for those who don't want to go to medical school. Students are getting more interested in interdisciplinary careers and applying biology to other fields, but information about those careers can be hard to find • Provide an introductory level seminar-style course on "What can you do with a biology degree?" that highlights different career opportunities • Advisors should be more aware of current opportunities and how to help students find information about potential careers
Better mentoring is needed	• More chances to find mentors besides just the academic advisor, whose time can be stretched thin • More organized system for peer mentoring, such as pairing underclassmen with upperclassmen in the same major for guidance
More chances to do research and/or learn how research is done	• Attendance at research seminars should be required or extra credit • Research experience in a professor's lab should be a required part of the curriculum; make these research experiences easier to find/access • Offer a course on experimental design and/or research methods
More chances to do research and/or learn how research is done *(cont.)*	• The campus brings in outside researchers to talk about what they do, but we don't know about the research in our own departments – have faculty lead seminars on their own work • Offer workshops for students who want to explore different lab techniques in more detail • Have a "shadow a professor for a day" activity where students learn how a research lab works

More opportunities/ interactions outside the classroom	• Greater encouragement of outside learning through group study, student affairs groups, discussions, etc. • More organized opportunities for students to engage in volunteer activities or outreach to the community; let them be role models for K-12 students (e.g. working with science fairs or with summer programs for high school students) • More study-abroad programs that are tailored for biology students: learn how science is done in other countries • Broaden the memberships in biology clubs – get more non-biologists involved • Use Facebook or other social networking sites to help create communities of students interested in similar topics
Teaching doesn't seem valued	• Students don't feel empowered to expect good teaching – the professors care more about their research. Increase the expectation of excellence in teaching – all professors should be familiar with educational theory, and there should be more professional development for faculty to enhance their teaching skills. Maybe pair new faculty with more experienced faculty who have demonstrated good teaching skills. • Instead of professors blaming the students for poor performance, encourage them to look at what they could do differently • More value on teaching the intro courses – we seem to get the least-interested professor. Offer some incentives for teaching these courses. • More avenues for student feedback – professors need to be attuned to what students want out of the class, what they feel they are missing, and students need to feel that they have a voice • There should be more 'face-time' with faculty (office hours or small discussion groups) • Sites like www.ratemyprofessors.com are popular with students, but not always embraced by campuses and often a venue for student complaints; maybe a more organized effort could be made to get all students to give and share feedback on courses so students can make more informed decisions and so faculty can see that student opinions are important and hold weight
More opportunities to develop	• Offer more courses on quantitative abilities including statistics, programming/computer science, technology, etc. tailored for biology students
More opportunities to develop communication	• More writing assignments in class and/or seminar courses on writing • More student presentations with chances for feedback
Less emphasis on competition	• Students feel that there is too much pressure to get "good grades" to get into graduate and professional programs. They are discouraged from trying new and different courses for fear of harming their GPA. Allow four "stretching your mind" courses – where at the end of the course you can opt out of having your course grade reported.

ABOUT THE AUTHOR

Marsha L. Matyas serves as the Director of Education Programs for the American Physiological Society (APS). Her research fields include factors affecting science and engineering interests and participation rates among women and minorities at the precollege, undergraduate, and graduate levels and curriculum development for biology education and professional development. She earned her master's degree in cell biology and her doctorate in science education at Purdue University. For eight years, she directed the Projects on Women in Science at the American Association for the Advancement of Science (AAAS) and served as a program officer at the National Science Foundation.

At the APS, Matyas directs a variety of programs, including: professional development programs for graduate and postdoctoral students and science educators, minority recruitment and retention programs at the precollege, undergraduate, and graduate levels; summer research experience programs for middle and high school science teachers; and a mentoring program for graduate and postdoctoral women in physiology. She also has extensive experience in program evaluation, including the development of live, online, and CD evaluation training programs. In addition, Dr. Matyas directs the APS' development and implementation of digital libraries of teaching resources, including a National Science Digital Library, the APS Archive of Teaching Resources.