Vision and Change: Perspectives and Proposed Actions from Scientific Societies

Invitational Summit on Undergraduate Biology: The Role of Disciplinary Societies

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

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
Exhibit at undergraduate research or teaching meetings	x	x	x	x	x	x	x	x		x			x	x	

	AAAS	AIBS	APS	ASBMB	ASCB	ASM	ASPB	Biophys. Soc.	BSA	ESA	GSA	SICB	SfN	SSE	NABT
(SACNAS, ABRCMS, CUR, NABT)															

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
Undergrad research is highlighted in print or online publication	x			x					X	x					

	AAAS	AIBS	APS	ASBMB	ASCB	ASM	ASPB	Biophys. Soc.	BSA	ESA	GSA	SICB	SfN	SSE	NABT
Undergraduate textbook 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 BioSciEd Net (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 in 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

New Activities/Topics	#	%

Provide online resources for curriculum & professional development

Review and expand digital library contents, users, and community building tools	5	33
Package online materials (journal articles, teaching resources, etc.) so 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 departments 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 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 crosscutting 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 ("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. Issues raised include:

- "Old school" lecture style is frustrating and not engaging
- Introductory courses are too broad
- Less emphasis on memorization
- More connections across the curriculum
- "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 to do research and/or learn how research is done
- More opportunities/interactions outside the classroom
- Teaching doesn't seem valued
- More opportunities to develop quantitative skills
- More opportunities to develop communication skills
- Less emphasis 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.

References

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 • 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 quantitative skills	• Offer more courses on quantitative abilities including statistics, programming/computer science, technology, etc. tailored for biology students
More opportunities to develop communication skills	• 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, she 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.