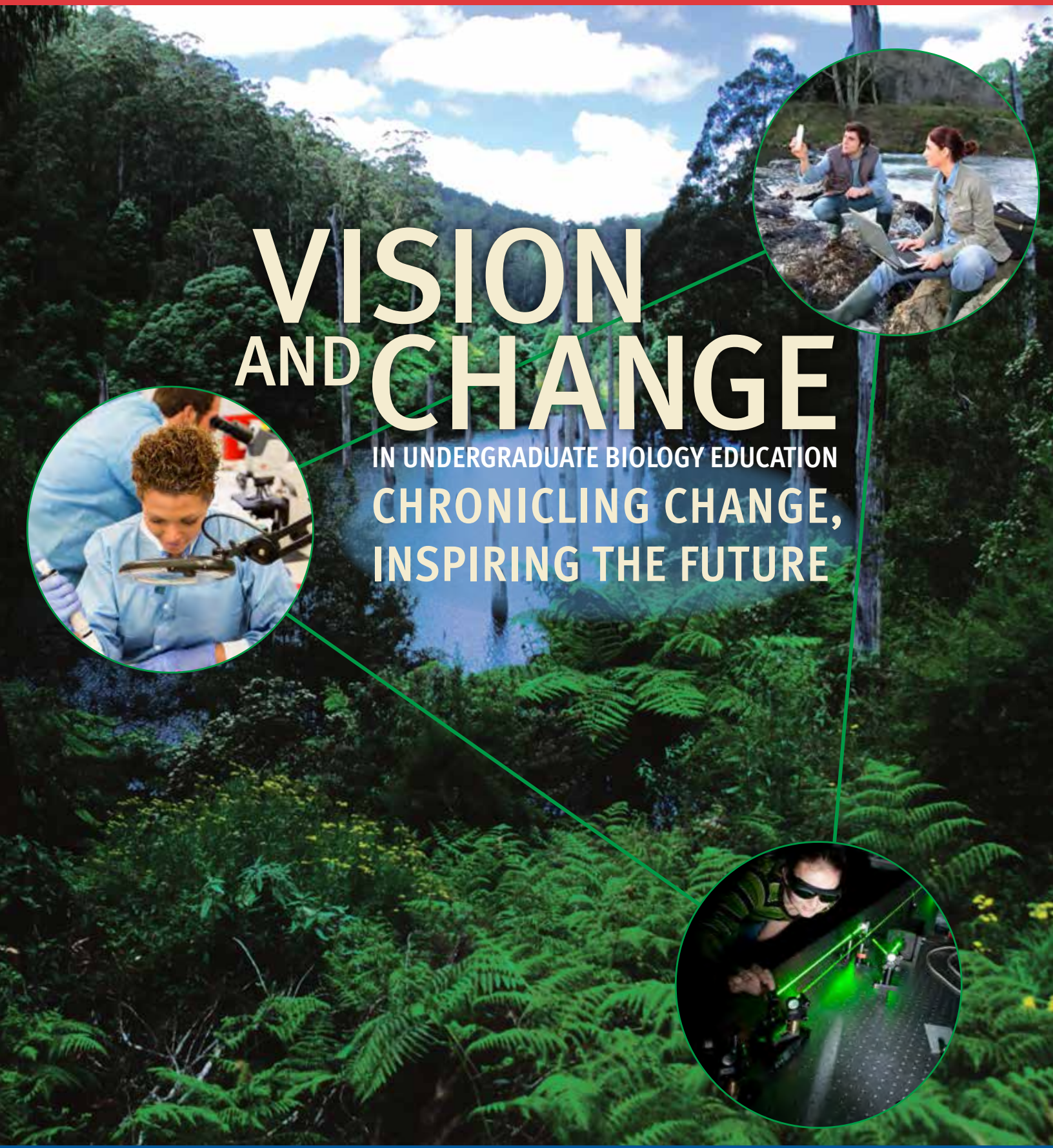

VISION AND CHANGE

IN UNDERGRADUATE BIOLOGY EDUCATION

CHRONICLING CHANGE, INSPIRING THE FUTURE

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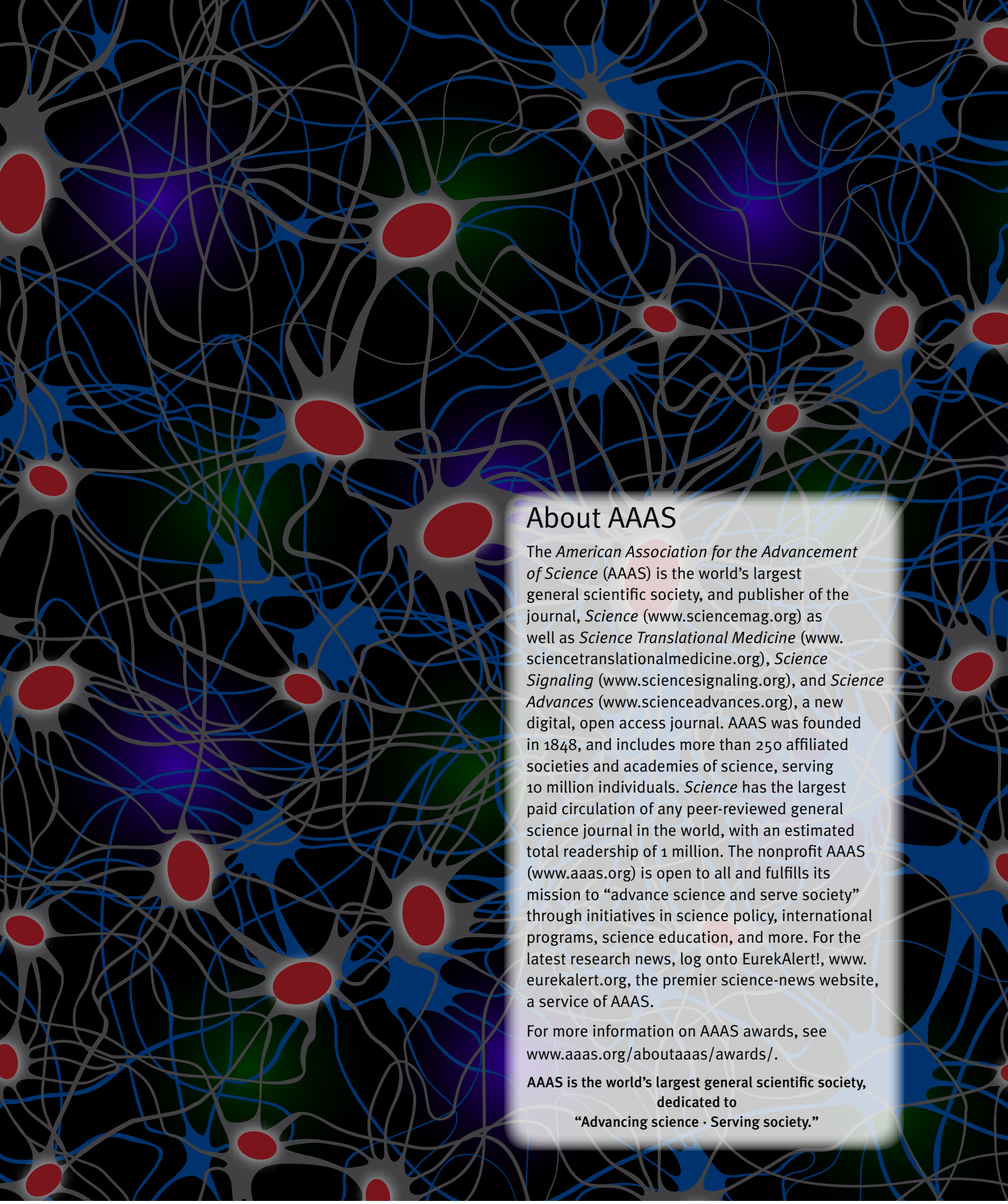

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CHRONICLING CHANGE, INSPIRING THE FUTURE

AMERICAN ASSOCIATION FOR THE
ADVANCEMENT OF SCIENCE

with support from the

NATIONAL SCIENCE FOUNDATION
Directorate for Education and Human Resources
Division of Undergraduate Education
and the
Directorate for Biological Sciences

NATIONAL INSTITUTES OF HEALTH

HOWARD HUGHES MEDICAL INSTITUTE

UNITED STATES DEPARTMENT OF AGRICULTURE

This publication is dedicated to Terry Woodin, NSF program director, who has tirelessly worked to promote change in undergraduate biology education and who has served as the chief "nudger" since the inception of the Vision and Change in Undergraduate Biology Education effort.

For more information on the AAAS Vision and Change in Undergraduate Biology Education Initiative, see www.visionandchange.org.

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VISION AND CHANGE

IN UNDERGRADUATE BIOLOGY EDUCATION

CHRONICLING CHANGE, INSPIRING THE FUTURE

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Diane Smith

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Colleagues,

Nearly a decade ago, a national experiment to transform undergraduate biology education was launched. A consensus on the essential elements needed to prepare undergraduates for data-intensive work in biology emerged from a series of regional meetings and a national conference. This consensus was captured in *Vision and Change in Undergraduate Biology Education,* a call to action for the community, with recommendations for implementation.

From sessions at professional society meetings to new departmental assessment plans, Vision and Change has been informing the future of undergraduate biology education since its release in 2009. A nationally validated tool, BioCore, was developed to elaborate and map the core concepts across the subdisciplines and provide a frame for faculty to integrate their own inspiration and expertise into the learning environments they create (www.biocore.wisc.edu/). Core concepts and learning goals now drive the infrastructure of CourseSource (www.coursesource.org/), an online tool for learning and teaching resources that emerged from the national Vision and Change conference and was informed by the work of the professional societies. The Partnership in Undergraduate Life Science Education (PULSE) fellows, a team of over 40 department chairs and deans selected through a competitive process, continue to develop innovative strategies ranging from tools to visiting teams aimed at transforming biology departments (www.pulsecommunity.org/). These are only a few of the hundreds of examples of changes in how future biologists are being prepared that have been inspired by Vision and Change. Many more are detailed in Chronicling Change, Inspiring the Future.

Throughout this process, four funding partners—the Howard Hughes Medical Institute, the National Institutes of Health, the National Science Foundation, and the United States Department of Agriculture—have worked together to nurture the implementation of the vision of a biology education that aligns with the reality of the rapidly changing nature of biology: a vision that demands conceptual, integrative, and critical thinking which crosses disciplinary boundaries and develops problem-solving skills and the ability to work with data at a scale previously unimaginable. This change is occurring in a context of shifting demographics and a growing need for a broad, inclusive biology workforce of biologists who think creatively together in addressing grand challenges surrounding the environment, food, energy, and health.

We are close to a tipping point in undergraduate biology education. Capturing the far-reaching effects of Vision and Change, the goal of this document and the 2013 Change conference that was skillfully managed by the American Association for the Advancement of Science, marks a pivotal time that provides a way forward. Join us in celebrating the inspirational work of the many and in reflecting as you continue to transform biology education. We look forward to the many changes that are still to come.

Sincerely,

Scott V. Edwards
Division Director
Division of Biological Infrastructure
Directorate for Biological Sciences
National Science Foundation

Susan R. Singer
Division Director
Division of Undergraduate Education
Directorate for Education and Human Resources
National Science Foundation

David J. Asai
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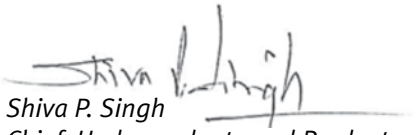

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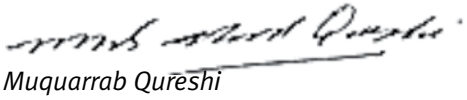


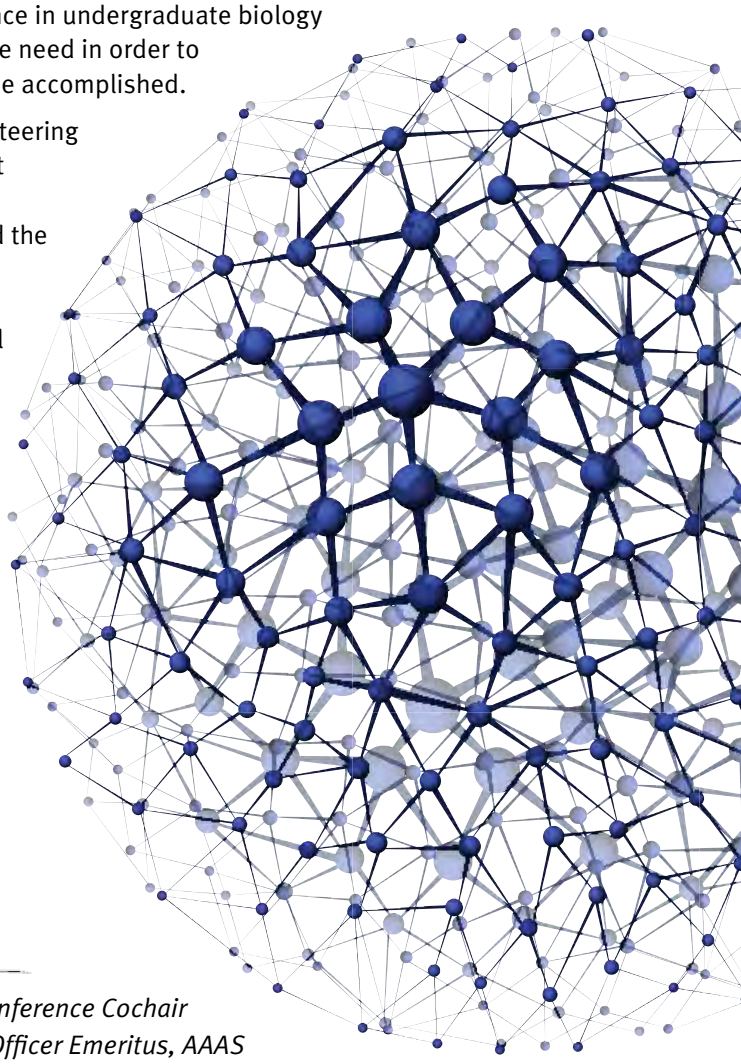
Muquarrab Qureshi
Deputy Director
Institute of Youth, Family, and Community
National Institute of Food and Agriculture
United States Department of Agriculture

LETTER FROM COCHAIRS

Dear Colleagues,

In the summer of 2009, hundreds of leading biologists, educators, administrators, and students convened in Washington D.C. to consider the status of undergraduate biology education and to chart a bold consensus vision to transform both how we teach and how we learn in the life sciences to ensure that all students gain a basic understanding of science as a way to understand the natural world. The result of the 2009 Vision and Change in Undergraduate Biology Education conference was a series of recommendations focused on core competencies and concepts that form the foundation of an undergraduate education in biology, strategies for creating a student-centered classroom, connecting teaching and learning through assessment, and a call for widespread opportunities for faculty to develop their teaching skills so that their courses will be more effective for all the students who enter their classrooms. Participants left the meeting united in their determination to be a force for transforming the undergraduate experience in biology by refocusing biology courses and curricula on the conceptual framework on which the science is built and from which discoveries emerge.

Four years later, this learning community reconvened to take stock of what had been accomplished, what we had learned, and the kinds of tools and strategies that have worked to connect teaching with learning. Emerging from this intensive collaborative meeting are the stories in this report that document how faculty, administrators, and students have come together to lead change, to cultivate faculty as agents of change, to set forth specific strategies for changing the student experience in undergraduate biology curricula, and to present examples of the kinds of evidence we need in order to evaluate how successful we have been and what remains to be accomplished.



As cochairs of the Vision and Change initiative, we thank our steering committee for its guidance and vision, and all of our important collaborators—the National Science Foundation, the National Institutes of Health, the Howard Hughes Medical Institute, and the United States Department of Agriculture—for their leadership and support. We also thank the hundreds of biologists, educators, administrators and students who answered the call to lead change at their institutions. These are their stories.

The stories in this report of change and innovation in undergraduate biology education reinforce our conviction that the time has never been more critical to rethink what and how we teach, in a way which ensures that the biology we teach engages all students and reflects the biology we practice in the laboratory and the field. We hope that this chronicle of change inspires the work ahead for all of us so that the students we train today are well prepared to use biological tools to address the societal challenges that will surely arise in the future. Much has been accomplished; much remains to be done.

Sincerely,

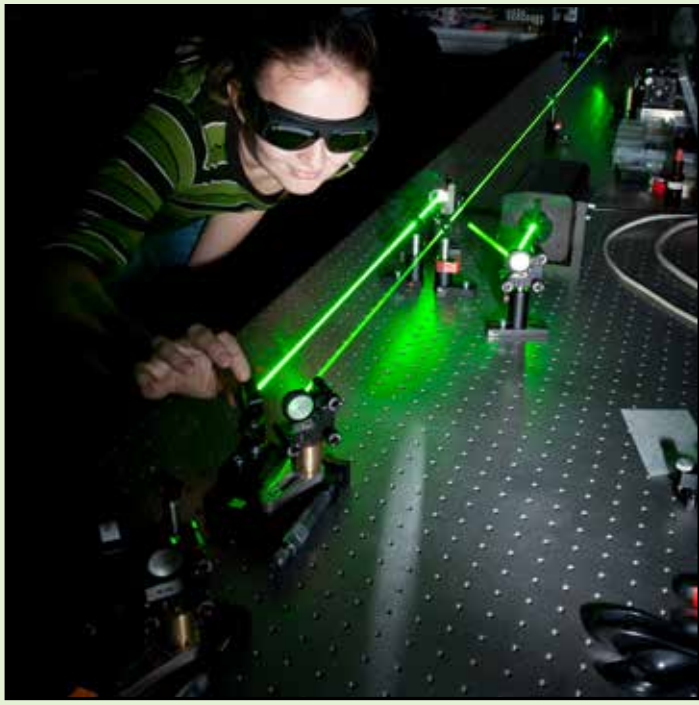
Carol Brewer, Conference Cochair
Professor Emeritus of Biological Sciences
University of Montana

Alan Leshner, Conference Cochair
Chief Executive Officer Emeritus, AAAS

SIGNS OF CHANGE IN UNDERGRADUATE BIOLOGY EDUCATION

Yolanda S. George, Tarrick Clayton, and Shirley M. Malcom,
American Association for the Advancement of Science (AAAS)

Introduction and Objectives



Reports such as *Vision and Change* and the many that preceded and followed it [e.g., the National Research Council's (NRC's) *Biology 2010* (NRC, 2003), the 2012 report of the President's Council of Advisors on Science and Technology (PCAST, 2012), and the 2012 NRC report on discipline-based education research (NRC, 2012)] have emerged over the years and generated needed momentum for transforming undergraduate education in biology. The ensuing ripples of concern about the state of undergraduate biology education have resulted in some good ideas and exciting projects that could serve as examples of what works. To capture what was happening as a result of the Vision and Change initiative, AAAS and its advisors and collaborators implemented a project to

- Chronicle outcomes of the report and the initiative;
- Document the trajectory of change following the report; and
- Identify a set of exemplars of how the community could accomplish the changes needed in a variety of institutions.

Data collection efforts included conducting a series of online activities and a conference titled "Vision and Change in Undergraduate Biology: Chronicling the Changes."

Partners in this effort include the National Science Foundation (NSF); Howard Hughes Medical Institute (HHMI); the National Institutes of Health (NIH), National Institute of General Medical Sciences (NIGMS), Division of Training, Workforce Development, and Diversity (TWD); and the United States Department of Agriculture (USDA), National Institute of Food and Agriculture (NIFA). The Vision and Change Advisory Board was led by Carol Brewer, cochair of the Board and former associate dean, College of Arts and Science, and professor emerita of biology, University of Montana; and Alan I. Leshner, then chief executive officer of AAAS and executive publisher of *Science*.

The Vision and Change activities associated with collecting abstracts focused on identifying examples of strategies that were being used by colleges and universities, and by professional societies, to foster change. The Vision and Change conference served as a vehicle for bringing together faculty, administrators, staff in teaching and learning centers, and graduate students and postdocs to identify strategies related to

- How to lead change;
- How, as a faculty member (including all instructional staff), to be an agent of change;
- How to change the student experience;
- How to build networks for change;
- How to amass evidence of change; and
- How to use the evidence amassed to evaluate change.

Questions in the abstract and in the online conference registration tool focused on identifying

- How the Vision and Change report was being used to promote change at both the departmental and the institutional level;
- Challenges encountered in instituting change;
- The course level(s) at which strategies are being focused;
- The types of approaches that are being used to change undergraduate biology education; and
- Sources of funding for change activities.

Also, Google Scholar was used to identify citations of the Vision and Change report and its presence on the World Wide Web.

Summary of Findings

The following are highlights from the findings:

- With the help of professional societies and collaborative efforts such as the Partnership for Undergraduate Life Science Education (PULSE), the Vision and Change report is penetrating the biology community. We have distributed nearly 7,200 copies of the report via conferences and in response to requests from individuals, and the number of Google Scholar citations was 237 as of the end of April 2015 (Table 1). Google analytics indicate that, between 2010 and December 2014, the Vision and Change website had 45,625 users (Table 2) and a little over 144,000 page views.

  Also, a 2014 report indicates that the Vision and Change report is frequently cited in NSF Transforming Undergraduate Education in Science, Technology, Engineering and Mathematics (TUES) proposals and appears to serve as the foundation for the design of proposed projects (Vasaly et al., 2014).
- Much of the focus in changing undergraduate biology education appears to be on introductory biology (115, or 63.9%).
- The major type of approach being used to change undergraduate biology is a change in classroom approach (104, or nearly 58%).
- Many departments are using the Vision and Change report as a guide for change across the department as they revise what and how they are teaching (172, or 50%).
- A plurality of departments and institutions (149, or 43.3%) are working on new assessment approaches to document the effects of their changed approaches in undergraduate biology, and many are working with their science education faculty or center for learning and teaching to help with the change in undergraduate biology (115, or 33.4%).
- Major challenges encountered in instituting changes in undergraduate biology appear to be a shortage of faculty time to plan and implement change (286, or 83.1%); the need for faculty professional development regarding effective teaching strategies (229, or 66.6%); and faculty concerns about the breadth of course coverage (215, or 62.5%).
- Although NSF, HHMI, NIH, and other organizations have provided some funding for implementing the Vision and Change recommendations, faculty and others appear to be just as likely to implement recommendations without external support (73/180, or 40.6%).

TABLE 1: Number of Google Citations for Vision and Change Report, by Year
*Number is through April 2015

Year	Citations
2010	6
2011	18
2012	30
2013	67
2014	83
2015*	33
	237

TABLE 2: Number of Users for Vision and Change Website, by Year
*Number is through April 2015

Year	Number of Users
2010	1,925
2011	6,454
2012	8,144
2013	12,130
2014	12,154
2015*	4,818
	45,625

Findings

Data from 180 abstracts submitted for the Vision and Change conference in July 2013 indicate that

(a) Many respondents (115, or 63.9%) were focused on changes in introductory biology; 58, or 32.2%, indicated that they were focusing on changes in upper-division courses; and 75, or 41.7%, said that they were concentrating their change efforts across the curriculum (Table 3).

(b) The major types of approaches being used to change undergraduate biology were changes in classroom methods or styles (104, or nearly 58%); the development of materials used (89, or nearly 50%); a mixture of all approaches (84, or nearly 47%); the implementation of assessment (75, or about 42%); and faculty development (63, or 35%). Among other approaches was adding to the literature on how people learn (29, or 16.1%) (Table 4).

(c) In the acknowledgments given in the abstracts collected, 73, or 40.6%, of the respondents indicated no funding source for their change efforts; 71, or 39.4%, acknowledged NSF support; 34, or 18.9%, recognized HHMI; 13, or 7.2%, acknowledged NIH support; and 23, or 12.8%, cited other funders, such as USDA, Lumina, Vulcan, Keck, Bechtel, and boards of regents (Table 5).

Respondents could provide multiple answers to these questions.

TABLE 3: Changes in Courses (*N* = 180)

Course Changes	Number	Percent
Introductory biology courses	115	63.9
Upper-division biology courses	58	32,2
Across the biology curriculum	75	41.7

TABLE 4: Approaches to Change (*N* = 180)

Types of Approaches	Number	Percent
Changes in classroom methods or styles	104	57.7
Materials development	89	49.4
Assessment	75	41.6
Faculty development	63	35.0
Other	29	16.1

TABLE 5: Funding Sources for Change (*N* = 180)

Funding Sources	Number	Percent
No funding source	73	40.6
National Science Foundation	71	39.4
Howard Hughes Medical Institute	34	18.9
USDA, foundations, and others	23	12.8
National Institutes of Health	13	7.2

When the 344 Vision and Change participants registered for the conference in July and August 2013, they were asked how they had used the Vision and Change report to promote change at the department and institutional level:

- 172, or 50%, of the respondents indicated that they were using Vision and Change as a guideline for change across the department as they revise what and how they are teaching.
- 149, or 43.3%, of the respondents indicated that they were working on new assessment approaches to document the effects of their changed approaches.
- 115, or 33.4%, of respondents indicated that they had worked with their science education faculty or their center for learning and teaching to help with the change.
- 106, or 30.8%, indicated that they had read the Vision and Change report as a means of revisiting what and how their department was teaching and why the department was teaching it.

Table 6: Uses of Vision and Change Report to Promote Change (*N* = 344)

	Number	Percent
a. Using it as a guideline for change across the department as we revise what and how we are teaching	172	50.0
b. Working on new assessment approaches so that we can document the effects of our changed approaches	149	43.3
c. Worked with our science education faculty or education faculty or center for learning and teaching to help with the change	115	33.4
d. We have read it as a department in order to revisit what we are teaching, how we are teaching it, and why we are teaching it	106	30.8
e. Included graduate students and postdocs in our discussions	68	19.8
f. Brought in outside experts to help with change	50	14.5
g. We have not used it to promote change at the department or institutional level	45	13.1

- 68, or about 19.8%, of the respondents indicated that they included graduate students and postdocs in their discussions of the Vision and Change report.
- 50, or 14.5%, indicated that they brought in outside experts to help with change in undergraduate biology.

Respondents could provide multiple answers to this question (Table 6).

When the 344 Vision and Change participants registered for the conference in July and August 2013, they were asked about challenges they encountered in instituting changes:

- 286, or 83.1%, indicated that their faculty needed more time to plan and implement change.
- 229, or 66.6%, indicated that their faculty needed some professional development regarding how to introduce new teaching practices.
- 215, or 62.5%, indicated that their faculty were concerned about the breadth of course coverage.
- 155, or 45.1%, indicated that they needed course modules demonstrating effective teaching practices.
- 143, or 41.6%, indicated that their faculty were concerned that students will not know as much or do as well on tests such as the Medical College Admission Test (MCAT).
- 113, or 32.9%, indicated that their faculty were concerned about undergraduate student assessments.
- 107, or 31.1%, indicated that their they needed videos demonstrating effective teaching practices.
- 78, or 22.7%, indicated that their they needed time in their class schedules to introduce courses requiring odd blocks of time.

TABLE 7: Challenges to Implementing Vision and Change Recommendations (*N*=344)

	Number	Percent
a. Faculty time to plan and implement change	286	83.1
b. Faculty need for some professional development in how to introduce new teaching practices	229	66.6
c. Faculty concern about the breadth of course coverage	215	62.5
d. Need for course modules demonstrating effective teaching practices	155	45.1
e. Faculty concern that students will not know as much or do as well on such tests as the MCAT	143	41.6
f. Faculty concerns about undergraduate student assessment	113	32.9
g. Need for videos demonstrating effective teaching practices	107	31.1
h. Time in the class schedule to introduce courses requiring odd blocks of time	78	22.7

Respondents could provide multiple answers to this question (Table 7).

Other Signs of Change

A. Google Scholar indicates that the Vision and Change report had 237 citations as of the end of December 2014 in journals such as *Cell Biology Education, Advances in Physiology Education,* the *Journal of Microbiology and Biology Education, Genetics, BioScience, Ecological Restoration,* the *Journal of Undergraduate Neuroscience Education,* and the *American Journal of Physics.*

B. In 2009, the NSF Directorate for Biological Sciences (BIO) established the Research Coordination Network—Undergraduate Biology Education (RCN—UBE) track of the RCN program. The goal of the program is to advance knowledge in a particular field or create new directions in research or education by helping groups of investigators to communicate and coordinate their research, training, and

educational activities across disciplinary, organizational, geographic, and international boundaries. The RCN—UBE track focuses on any topic that is likely to lead to improved participation, learning, or assessment in undergraduate biology curricula. Since 2009, 36 RCN—UBE projects have been funded. Seventeen were smaller "Incubator" awards and nineteen were full awards, including seven full projects that started as "Incubators" (Vasaly, et al., 2013; and www.nsf.gov/funding/pgm_summ.jsp?pims_id=11691&org=BIO).

C. In 2012 the funders of Vision and Change formed PULSE, an action and outreach collaborative of biological science department chairs and interested deans. PULSE activities include

- ***Taking the PULSE:*** Distributing self-assessment rubrics to aid departments in evaluating their progress vis-á-vis the Vision and Change initiative;
- ***Spreading the PULSE:*** Producing teams of Vision and Change "ambassadors" who will visit campuses to facilitate productive conversations and strategic planning in order to promote change, as well as to help departments assess the impacts of reform efforts;
- ***Raising the PULSE:*** Establishing a broad public-relations campaign to inform the entire life sciences education community about Vision and Change, about networking opportunities for agents of change, and about online and regional workshops to help departments engage in Vision and Change reform; and
- ***PULSE Regional Networks:*** Testing the resources developed by other groups (on a regional scale) in the Pacific Northwest, the Midwest and Great Plains states, New England, the Southeast, and the Southwest.

PULSE products include

- A framework for departmental change (www.pulsecommunity.org/page/pulse-framework);
- The PULSE Vision and Change rubrics, which articulate fundamental criteria for evaluating the level of adoption of the principles of Vision and Change in life science departments (www.lifescied.org/content/12/4/579.full); and
- The PULSE Online Toolkit, which includes other resources for promoting individual and collective change (www.pulsecommunity.org/page/online-toolkit-test).

D. A network of professional societies, the Professional Societies Alliance for Life Science Education (PSALSE), was formed in 2013 after the Vision and Change conference (www.aibs.org/education/life_science_societies.html). The objectives of the network are to identify the next steps to follow regarding the ideas that emerged from the conference and to determine and implement collective strategies for achieving the requisite transformation in college and university life sciences education.

E. Methods used within Vision and Change to engage a community to consider the educational needs within its discipline are now being used as a model to consider changes in their own discipline, including geosciences and engineering (www.jsg.utexas.edu/events/future-of-geoscience-undergraduate-education/ and Besterfield-Sacre, et al., (2014). Vision and Change methods are also being used by the Association of American Universities Undergraduate STEM Education Initiative (www.stemedhub.org/groups/aau).

References

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VISION AND CHANGE, 2013

INTRODUCTION

In 2013, the American Association for the Advancement of Science (AAAS), in collaboration with the National Science Foundation (NSF), the Howard Hughes Medical Institute (HHMI), the National Institute of General Medical Sciences of the National Institutes of Health (NIGMS-NIH), and the U.S. Department of Agriculture's National Institute of Food and Agriculture (USDA-NIFA), hosted a national conference to continue advancing the goal of improving undergraduate biology education for all students. This 2013 national conference built on the progress made at colleges and universities around the country in the aftermath of a groundbreaking series of meetings organized by AAAS in 2008 and 2009 to improve undergraduate biology education (www.visionandchange.org).

As described in this report, representatives from 178 colleges and universities and 11 professional organizations met to discuss the advances made following the national conference in 2009 and to explore and better understand how change happens in undergraduate biology education. Participants made one theme particularly clear: Although changes within the practice of biology often happen with lightning speed, changes to educational practice and the curriculum generally require both time and patience. But as participants also emphasized, even though curricular change occurs slowly, with a clear vision and leadership, change is possible. Indeed, it is occurring nationwide.

Vision and Change: A Brief History

In 2006, a small group from the NSF's Directorates for Education and Human Resources and for Biological Sciences joined with leaders from HHMI to develop a shared vision for the future of undergraduate biology education and the changes needed to achieve it. Motivated by significant advances underway in the biological sciences and emerging research in the science of learning, these innovators, joined by leaders from the NIH, recommended conducting a series of conversations with college and university faculty and administrators around the country. In these forums, biology educators could identify the changes that needed to take place, discuss how to effect those changes, and explore how best to support efforts for change. Ultimately, the goal was to help define and advance a shared vision for the future of undergraduate biology education.

In 2008, with this vision in mind, AAAS organized six regional conversations with leading biology faculty, administrators, students, and professional organizations. Their charge was to identify effective undergraduate biology education practices on campuses around the country. In 2009, partly on the basis of the findings of the regional conversations, AAAS hosted a national conference in Washington, D.C., to continue the conversations that took place at the regional conferences. More than 500 biologists and others attended this first national conference, representing a broad base of both institutions of higher learning and areas of interest. These meetings in turn resulted in a major report published by AAAS: *Vision and Change in Undergraduate Biology Education: A Call to Action* (2011), which recommended specific actions aimed at improving undergraduate biology education nationwide:

- integrate core concepts and competencies throughout the curriculum;
- focus on student-centered learning;
- promote a campuswide commitment to change; and
- engage the biology community in the implementation of change.

Since that nationwide call to action, colleges and universities around the country have worked to improve their own biology education curricula to ensure that all undergraduates have the basic biology knowledge, skills, and conceptual understanding they will need to participate as informed citizens and thrive in the modern world. As an indication of how critical educational leaders have considered this work, many have developed and sustained Vision and Change–related projects with little or no external support.

Chronicling Change, Inspiring the Future

In 2013, educational leaders with a commitment to improving undergraduate biology education reconvened in Washington to assess the advances made up to that time in achieving the goals of Vision and Change, as well as to inspire new leadership for the years ahead. This follow-up conference, which focused on "Chronicling Change, Inspiring the Future," included plenary sessions, panel discussions, and poster sessions highlighting successful projects and programs from around the country. Conference participants, including some of the nation's leading biologists, educators, researchers, and administrators, discussed how the original Vision and Change initiative had helped advance undergraduate biology education nationwide. In addition to emphasizing the importance of chronicling institutional change and documenting outcomes by using objective methods, the participants discussed progress made in realizing the vision set forth at the first national meeting, the challenges remaining in leading change, helping faculty act as agents of change, changing the student experience, building networks for change, and amassing evidence of change and its effects.

Working in small- and large-group settings, conference participants identified significant advances that had taken place in undergraduate biology education since the original 2009 Vision and Change call to action, highlighted strategies known to work, and identified what would still be needed to move forward in each topic area. Conference attendees also completed surveys designed to determine how successful Vision and Change efforts on their campuses had been to date, as well as the types of challenges they continued to face in improving undergraduate biology education.

The material that follows highlights the 2013 Vision and Change conference discussions and recommendations, and chronicles many of the accomplishments and challenges biologists and educators nationwide have faced in improving undergraduate biology education. It also synthesizes the road maps participants suggested for accelerating change and moving forward. Examples of programs inspired by the original Vision and Change initiative are highlighted throughout, with additional projects and programs listed in the appendix. For more information on these projects, visit the Vision and Change website at www.visionandchange.org/2013-conference-materials/ or contact the project leaders.

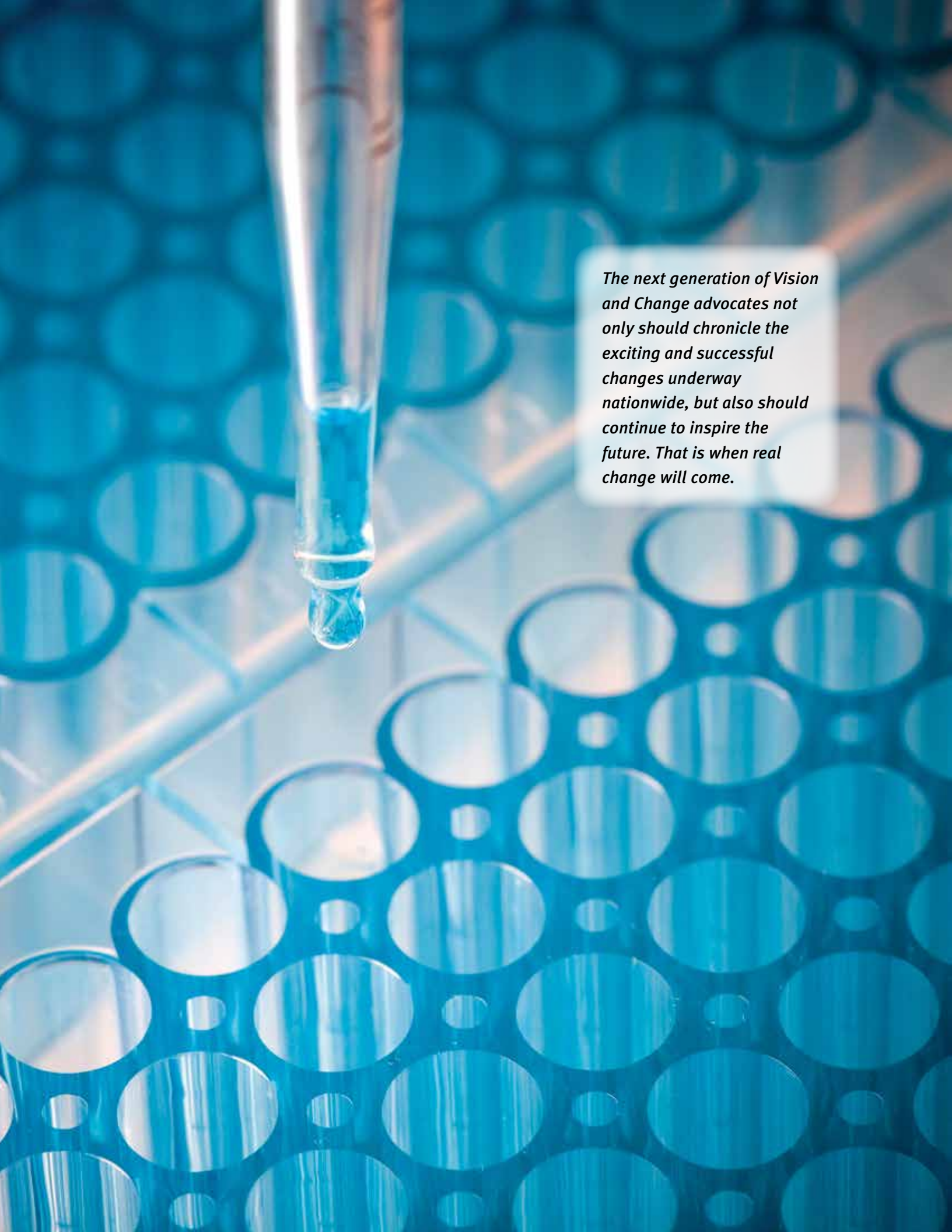
VISION AND CHANGE IN UNDERGRADUATE BIOLOGY EDUCATION: A CALL TO ACTION

The 2009 Vision and Change national conference resulted in a call to action to improve the teaching and learning of undergraduate biology. The key recommendations of the resulting report published by AAAS in 2011 included articulating the core life science concepts all undergraduates need to understand

- evolution;
- pathways and transformations of energy and matter;
- information flow, exchange, and storage;
- structure and function; and
- systems.

The 2011 report also identified the important need for undergraduates to understand not only the process of science, but also the interdisciplinary nature of the new biology and how science is closely integrated within society. In addition, students should be competent in communication and collaboration, as well as have a certain level of quantitative competency and a basic ability to understand and interpret data. Further, to be current in biology, students should have experience with modeling, simulation, and computational and systems-level approaches to biological discovery and analysis, and should be familiar with using large databases.

The complete report from the 2009 national conference, *Vision and Change in Undergraduate Biology Education: A Call to Action,* provided the blueprint for the follow-up conference in 2013. The original 2011 report is available online at www.visionandchange.org/files/2013/11/aaas-VISchange-web1113.pdf.



The next generation of Vision and Change advocates not only should chronicle the exciting and successful changes underway nationwide, but also should continue to inspire the future. That is when real change will come.

CHAPTER 1

LEADERS OF CHANGE

Since the original 2009 national conference, many leading biologists, educators, and administrators have worked to respond to the Vision and Change call to action to improve undergraduate biology education on their campuses. As part of the 2013 follow-up conference, organizers brought together some of the outstanding leaders who have been working to achieve the goals of Vision and Change within their organizations and on their campuses. These plenary speakers and panelists introduced innovative strategies for improving undergraduate biology education (and undergraduate science, technology, engineering, and mathematics—STEM—education generally), analyzed successful solutions to realizing the vision set forth, discussed setbacks, examined solutions to challenges, and shared methods and programs that have worked for others around the country.

Ultimately, these featured speakers argued, it comes down to leaders at all levels of an institution articulating a new vision for change that radiates out from the classroom, into the department, throughout the institution, and back to the classroom again. From increasing graduation rates for all students regardless of their majors, to effecting changes within a department, setting the direction for and implementing systemic and lasting change at colleges and universities requires leadership at a variety of levels.

IMPLEMENTING INSTITUTIONAL CHANGE

In his opening remarks, Mark Becker, president of Georgia State University (GSU), noted that national policymakers believe that 60% of the populace needs to have a college education if the nation is to maintain its competitive advantage in the new global economy. Given, however, that less than 30% of the nation meets this goal, something clearly has to change. In the case of GSU, Becker knew that, to improve its graduation rates (which had been at 32%), the university had to become more inclusive and more committed to student success, and *everyone* on campus had to bring a sense of urgency to the task at hand.

To that end, GSU spent close to a year defining a five-year strategic plan, and then campus leaders tested a variety of approaches that could achieve those goals. Throughout the process, campus administrators collected and analyzed data so that documented successes could be scaled up immediately. For example, the use of trained peer tutors and first-year student learning communities showed positive results, so GSU leaders introduced peer tutors into every class that had a high failure or withdrawal rate and required all entering freshmen to join a learning community unless they specifically requested to opt out.

GSU also addressed the financial issues that often force students to withdraw: The university began helping some undergraduates secure or regain scholarships and gave others small grants to encourage them to attend courses on how to manage their time and finances while improving their study skills. In addition, the campus centralized its advising structure so that students would have opportunities to meet with trained advisors who could help them keep on a path toward graduation.

Finally, GSU instituted a summer success program for underprepared students, concentrating all of the campus initiatives that had been proven successful (e.g., peer tutoring, development of study skills, and learning communities) into one intensive summer experience conducted before students began their first year at the university. This program helped prepare new students for the rigors of college-level work, and participants were found to perform as well as their better prepared peers. As a result, graduation rates at GSU have improved from 32% to 54% in just three years and are on track to reach 60%. As the university has demonstrated, leadership with a vision and a commitment to change can indeed make a real difference.

DRIVING EDUCATIONAL CHANGE

In a series of presentations, advocates of improving undergraduate biology education emphasized the critical role of leadership, but these national leaders also stressed the importance of financial support for change and of having data to provide evidence of the positive impacts. As Shirley Malcom, AAAS director of Education and Human Resources, noted in introducing the panel, change is not easy. And change takes time: Much like the civil rights leaders of the March on Washington 50 years ago (and, coincidentally, the anniversary of which occurred at the same time as the national meeting), advocates of change start with a dream, but then they persevere, often over many years and sometimes even decades, to make change happen.

Lorelle Espinosa, senior analyst at Abt Associates, presented a wealth of data collected over the last decade by Sylvia Hurtado, director of UCLA's Higher Education Research Institute (HERI). Hurtado's studies have looked at STEM fields from a variety of perspectives, including the use of student-centered teaching and how faculty pedagogy affects student success and students' perceptions of themselves as scientists. In addition to documenting what works, HERI studies have demonstrated the importance of creating partnerships to gather and analyze data and to maintain communication with colleagues so that everyone learns from one another's successes. Data from HERI are available at www.heri.ucla.edu/.

Thomas LeBlanc, executive vice president and provost at the University of Miami, focused on the power of the purse to both lead and implement change. As he noted, institutional support for improving undergraduate biology education can fund release time, create awards for innovative changes, pay for professional development, and provide the baseline funding needed for sustaining and institutionalizing successful new programs. New biology labs for first-year students, integrated science curricula, and bridge programs to assist students in making successful transitions to four-year campuses can be jump-started by external funding, but all require institutional support to be sustained. Administrators and other campus leaders need to provide faculty the resources and time they require to develop new programs, LeBlanc emphasized.

Mary Ann Rankin, senior vice president, provost, and professor of biology at the University of Maryland, College Park, also focused on how coalitions of leaders at all levels—from students to alumni—are important in implementing and sustaining change. For example, having highly respected faculty on a team encourages others to consider and eventually support changes to teaching and learning. Having the administration on board not only provides support for new programs, but also can help build awareness of those programs. And advice from outside experts can help identify critical issues in advance so that advocates of change can build on what is already known.

Robert P. Elde, dean of the College of Biological Sciences at the University of Minnesota, acknowledged the difficulty in enlisting some faculty in the effort to transform how undergraduate biology is taught. But he advised meeting participants never to underestimate the power of fully engaged students to transform faculty resistance to change. At the University of Minnesota, first-year biology majors attend a four-day "boot camp" at the campus biological research station as part of their orientation. This introductory course on the nature of life helps the new students build relationships with faculty and other students. It also sets the tone of doing authentic research as part of learning, and such research is continued on campus in active-learning classrooms. *Doing* biology, rather than simply learning about biology, has proven to be a transformative experience for many students. These student successes, coupled with strategic new faculty hires, have helped the campus bring about real change.

As noted by Shirley Malcom at the conclusion of the session, exciting students about the study of biology and actively engaging them in their own learning can indeed be transformative for both faculty and students. The next generation of Vision and Change advocates not only should chronicle these exciting and successful changes underway nationwide, but also should continue to inspire the future. That is when real change will come.

LEADERSHIP AND CHANGE IN UNDERGRADUATE BIOLOGY

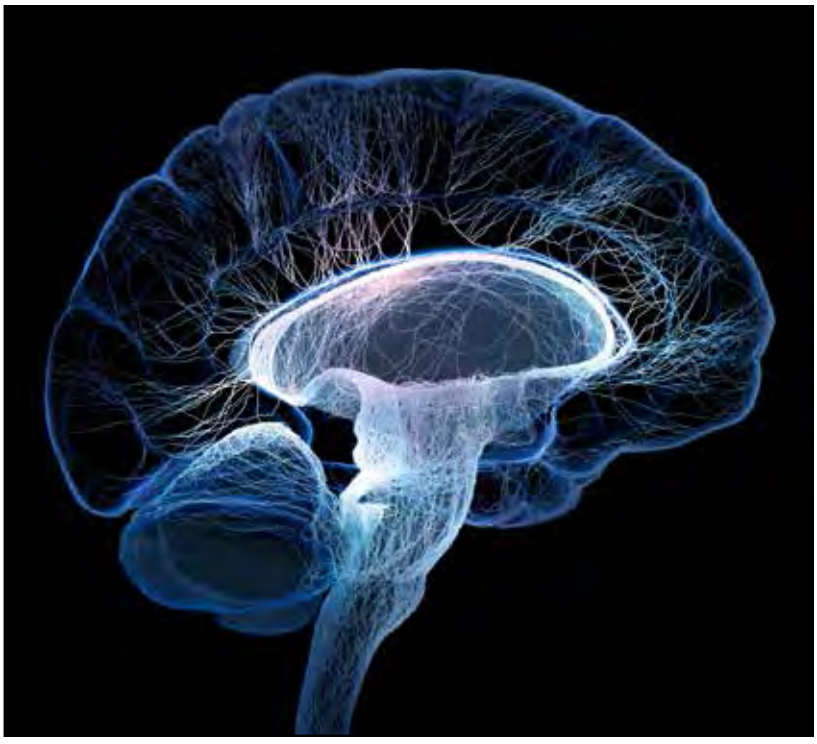
James Collins, professor in the School of Life Sciences at Arizona State University, opened his keynote address with a weather map from Hurricane Sandy in October 2012 and photographs of the resulting flooded shorelines, tunnels, subways, and streets that shut down transportation networks in New York City. He then asked everyone at the conference to think of undergraduate biology education as a similar "storm" with similar challenges and opportunities for the future. Part of the challenge in improving how biology is taught, Collins argued, is that the content and practice of the life sciences are changing so rapidly that educational institutions have not been able to keep pace. And, much as it is with a city transportation network literally under water, it is difficult to improve one component without addressing all parts of a complex system.

Collins's advice to those championing Vision and Change in undergraduate biology education is to seize the opportunity to implement institutionwide changes. Leaders of change need to define their values and then create a narrative that communicates those values to the education community at large. To implement changes on a comprehensive scale, leaders should build on what they know works and surround themselves with those who embrace change. For Collins, this goal means placing the process of discovery at the center of undergraduate education and creating a community of scholars to advance the teaching and learning of biology at all levels.

PARTNERSHIP FOR UNDERGRADUATE LIFE SCIENCES EDUCATION

In 2012, as a direct result of the first Vision and Change meeting, program officers from the NSF, HHMI, and NIGMS-NIH launched the Partnership for Undergraduate Life Sciences Education (PULSE), a community of scientists dedicated to the department-level implementation of the original Vision and Change recommendations on a national scale. PULSE focuses on departments because cultural and institutional change requires targeting reward structures, motivating faculty to focus on student learning, and developing and transferring skills between colleagues, most of which take place at the departmental level. Moreover, department chairs are often the people ultimately responsible for curriculum development, hiring decisions, teaching assignments, and faculty evaluations. At the same time, the heads of departments are familiar with how faculties view undergraduate education.

During the 2012–2013 academic year, 40 PULSE Fellows worked on pursuing the goals of Vision and Change within the PULSE framework. Using meetings, conference calls, advice from the PULSE steering committee, and input from others, the Fellows developed what they referred to as a Framework for Change. This framework, which serves as a guide for departments as they work through the original Vision and Change recommendations, includes advice on everything from raising awareness and building the capacity for change to hosting meetings on the goals of Vision and Change and supporting implementation and assessing results.



Other PULSE initiatives include the following:

- self-assessment rubrics to aid in evaluating departmental progress in implementing Vision and Change reforms;
- regional networks of institutions around the country working to implement the recommendations of Vision and Change;
- a cadre of traveling Vision and Change Ambassadors who visit campuses to facilitate productive conversations and strategic planning for promoting change, as well as to help departments assess the impacts of reform efforts;
- a broad outreach campaign to inform the entire life sciences undergraduate education community about Vision and Change networking opportunities and about online and regional workshops to help departments engage in reform; and
- a pilot program to develop a set of guidelines for departments to use in self-assessment in concert with visiting Pulse Fellows.

As speakers, panelists, and others noted throughout the 2013 conference, the key concepts and competencies presented in *Vision and Change: A Call to Action* have never been more critical. The vision for improving undergraduate biology education has been laid out before the biology community. Although the problems confronting colleges and universities are complex, change is indeed possible. Improving undergraduate biology teaching and learning for all students is a pressing and timely challenge that all institutions can embrace.

PULSE

The Partnership for Undergraduate Life Science Education (PULSE) was launched by program directors at Howard Hughes Medical Institute (HHMI), the National Institutes of Health's National Institute of General Medical Sciences (NIH/NIGMS), and the National Science Foundation (NSF) to catalyze the implementation of recommendations made in the 2011 report *Vision and Change in Undergraduate Biology Education: A Call to Action* (www.visionandchange.org/finalreport).

In August 2012, 40 Vision and Change Leadership Fellows were selected after an application-and-peer-review process managed by the American Institute for Biological Sciences. Fellows met during two workshops held at HHMI Headquarters in Chevy Chase, MD, and facilitated by Knowinnovation, a British firm that seeks to accelerate multidisciplinary scientific innovation. The Fellows were challenged to develop a framework for implementing the Vision and Change recommendations that would be based on their collective experience as current or former department chairs or deans. Approximately equal numbers of Fellows were selected from community colleges, liberal arts colleges, comprehensive universities, and research-intensive universities from around the country. Instead of generating another report, the Fellows opted to form working groups to advance the ideas in the Vision and Change report.

At the end of the yearlong fellowship in August 2013, the Fellows' work was just getting started. They organized into three major working groups and four regional networks to expand the impact of PULSE activities. From the original group of 40 Fellows, 35 are still active members; nine new Fellows were introduced at the fourth Fellows workshop held at HHMI in February 2015. A new application process is being developed to select additional Fellows. The PULSE community now has over 1,500 members. A complete list of members, regional networks, working groups, rubrics for departmental self-assessment, an upcoming meetings, and other resources, including an Online Toolkit, can be found at the PULSE website, www.pulsecommunity.org.

The activities of the working groups for Certification (Taking the PULSE) and Outreach (Raising the PULSE) and of Vision and Change Ambassadors (Spreading the PULSE), as well as the activities of several regional networks, are supported by awards from the National Science Foundation. Two additional awards support the evaluation of PULSE Fellows' activities and coordination among the different working groups. Many of these awards extend the PULSE activities into 2015 and beyond.

40 ORIGINAL VISION AND CHANGE LEADERSHIP FELLOWS

NAME	INSTITUTION
Karen Aguirre	Coastal Carolina University
Taylor Allen	Oberlin College
Judy Awong-Taylor	Georgia Gwinnett College
Teresa Balser	University of Florida
Gita Bangera	Bellevue College
Edwin J. Barea-Rodriguez	University of Texas at San Antonio
Heather Belmont	Miami Dade College
Loretta Brancaccio-Taras	Kingsborough Community College
Richard Cardullo	University of California–Riverside
Jonathan Cumming	West Virginia University
William Davis	Washington State University
Betsy Desy	Southwest Minnesota State University
Alix Fink	Longwood University
Ellen Goldey	Wofford College
Richard Gonzalez	University of San Diego
Sharon Gusky	Northwestern Connecticut Community College
April Hill	University of Richmond
Thomas Jack	Dartmouth College
Nitya Jacob	Oxford College of Emory University
Michael Kelrick	Truman State University
Karen Klyczek	University of Wisconsin–River Falls
Melanie Lee-Brown	Guilford College
David Marcey	California Lutheran University
Kate Marley	Doane College
Jenny McFarland	Edmonds Community College
Kathryn Miller	Washington University in St. Louis
Marcy Osgood	University of New Mexico
Joann Otto	Western Washington University
Pamela Pape-Lindstrom	Everett Community College
Cynthia Peterson	University of Tennessee
Jo Anne Powell-Coffman	Iowa State University
Todd Primm	Sam Houston State University
Gary Reiness	Lewis & Clark College
Sandra Romano	University of the Virgin Islands
Joel Schildbach	Johns Hopkins University
Whitney Schlegel	Indiana University
Gina Semprebon	Bay Path University
Mary Smith	North Carolina Agricultural and Technical State University
Akif Uzman	University of Houston, Downtown
Gabriele Wienhausen	University of California, San Diego

PREPARING FACULTY TO ENGAGE IN VISION AND CHANGE

Grant Gardner, Assistant Professor, Mathematics and Science Education,
Department of Biology, Middle Tennessee State University

Goals: To furnish information about the state of biology education research (BER) and relevant findings, to translate BER results into practical solutions for classroom instruction, and to provide sustained support and collaborative networks to implement research-based instructional strategies in the classroom.

Project Overview: This project promotes faculty professional development that aligns with Vision and Change. Included in such development are enhancing faculty scientific and pedagogical expertise; encouraging the development of a community of scholars–educators; engaging faculty in regular conversations and peer-to-peer mentoring about teaching and learning; and improving, testing, and sharing an understanding of how students learn.

Methods and Strategies: The Biology Department at Middle Tennessee State University has created a semester-long graduate course for all doctoral students that engages them in the BER literature, helps them develop a teaching portfolio for future employment, and gives them experience with developing exercises to promote active learning in the undergraduate biology classroom. The department also invites one education researcher per year to present a seminar as part of the regular departmental seminar series. A discussion group and teaching workshop are part of the seminar, giving faculty an opportunity to present their research results related to the seminar, to consider challenges to implementing research-based instructional strategies in their own classrooms, and to collaborate with other faculty on these issues.

Evaluation: The graduate course uses pre- and postassessment instruments to measure student perceptions of teaching and learning as well as to evaluate the philosophical alignment of various teaching approaches with reform-based teaching methods. Data sources include survey instruments, student teaching portfolios, and observations of students presenting an originally designed teaching module.

Impacts to Date: As a result of the graduate course, 16 biology graduate students have developed teaching portfolios. These portfolios have helped several of them to secure employment in academia, provided them with time to reflect on their own philosophies of teaching and learning, given them awareness and access to teaching resources, and made them literate in the BER literature. In addition, several students are publishing original biology teaching exercises in a practitioner journal (*The American Biology Teacher*). The faculty development workshop has opened avenues of interdepartmental dialogue on matters of undergraduate teaching and learning. Following a seminar and workshop by Dr. Robert Beichner, who conducts evaluation research on active-learning techniques in classrooms participating in a program called Student-Centered Active Learning Environment for Undergraduate Programs (SCALE-UP), one faculty member secured funding to convert a biology lecture hall into a SCALE-UP classroom. The majority of first-semester introductory biology courses for majors will soon be moved into these classrooms to promote active learning.

Unexpected Challenges: Recruiting individuals of national standing to lead the seminars is difficult without a source of funding, as is finding the time to plan and implement the workshops. Another challenge is faculty who do not see the seminars as worth their time. Oftentimes, these are the faculty who would be best served by attending the seminars. This issue is ongoing and one that only a methodical change in departmental and university culture will alleviate.

Dissemination: Data on the graduate teaching class are currently being analyzed and will be disseminated in research journals and conferences in the near future.

Acknowledgments: Carol Goodwillie helped to plan and implement the faculty seminar and workshop. Department head Jeff McKinnon continues to support a culture of evidence-based teaching in the department.

A MODEL FOR EMERGENT CHANGE

Jo Anne Powell-Coffman, Professor and Chair, Genetics, Development and Cell Biology, and Craig Ogilvie, Clark Coffman, Emily Elliott, and Diane Bassham, Iowa State University

Goals: To increase student engagement and learning in first- and second-year science courses and to graduate more science majors who will be prepared to address complex, real-world problems.

Project Overview: This project seeks to create an intellectually vibrant environment that drives pedagogical innovation and inspires and coordinates simultaneous changes in several science departments so that each student will benefit from multiple transformed courses during his or her first two years. Faculty are adding inquiry activities to introductory lectures and labs, including extended five- to six-week research projects in first- and second-year lab courses so that every student has the experience of designing experiments and considering solutions to real-world problems.

Methods and Strategies: The project focuses on emergent change and includes faculty communities devoted to learning curricular innovation and implementation, as well as postdoctoral science education fellows who bring energy, time, expertise, and a sense of urgency to reforms. These communities help coordinate faculty efforts and provide a platform for discussions of how best to implement strategies for transforming the undergraduate experience.

Evaluation: The project tests the hypothesis that course transformations will correlate with increased student continuation in STEM majors. The project assesses student learning and student attitudes in transformed courses, and faculty are repeatedly evaluating student progress toward course objectives. Colleagues in the School of Education are helping implement the Student Understanding of Science and Scientific Inquiry (SUSSI) instrument to assess students' conceptions about the nature of science. Faculty are also surveyed, to evaluate changes in departmental or institutional cultures and practices.

Impacts to Date: In 2012, approximately 4,000 students took lecture courses with increased active-learning emphases; about 8,000 students are expected to do so in 2013. In 2012, approximately 630 students benefited from lab courses with new extended research projects, and the number is expected to increase to around 850 in 2013. In the years before the project began in 2011 (i.e., with students who entered the university in the fall of 2006, 2007, or 2008), the one-year retention rate in STEM majors was 74.5% ± 0.5%. For students who entered in the fall of 2011 or 2012, the one-year retention rate was 77.3% ± 0.8%, an increase of 2.8% ± 0.9%. In addition, 89% of the biology faculty participating in learning communities, as well as 48% of their peers in other departments, stated that they had worked to improve their teaching over the past year. More than 80% of the biology faculty surveyed concluded that their departmental colleagues supported efforts to improve teaching.

Unexpected Challenges: Enrollment in introductory biology courses has increased 27% since 2009. These high enrollments present both tremendous opportunities and great challenges, two of which are trying to introduce active learning in classes of up to 400 students and coordinating courses taught in multiple sections by different teams of instructors. Incremental improvements in the courses require patience and good data.

Dissemination: For a study of the faculty learning communities, see Addis, E.A., Quardokus, K.M., Bassham, D.C., Boury, N.M., Coffman, C.R., and Powell-Coffman, J.A., *Journal of College Science Teaching,* 2013.

Acknowledgments: This project is supported by a grant from HHMI. Other co–principal investigators on the grant are Cinzia Cervato, Tom Greenbowe, and Gene Takle. Pedagogical innovations reflect the dedication and scholarship of the faculty instructors.

CSUPERB: A SYSTEMWIDE BIOTECH COMMUNITY PROMOTING CHANGE

Susan Baxter, Executive Director, Program for Education and Research in Biotechnology, and James Henderson, California State University, Los Angeles

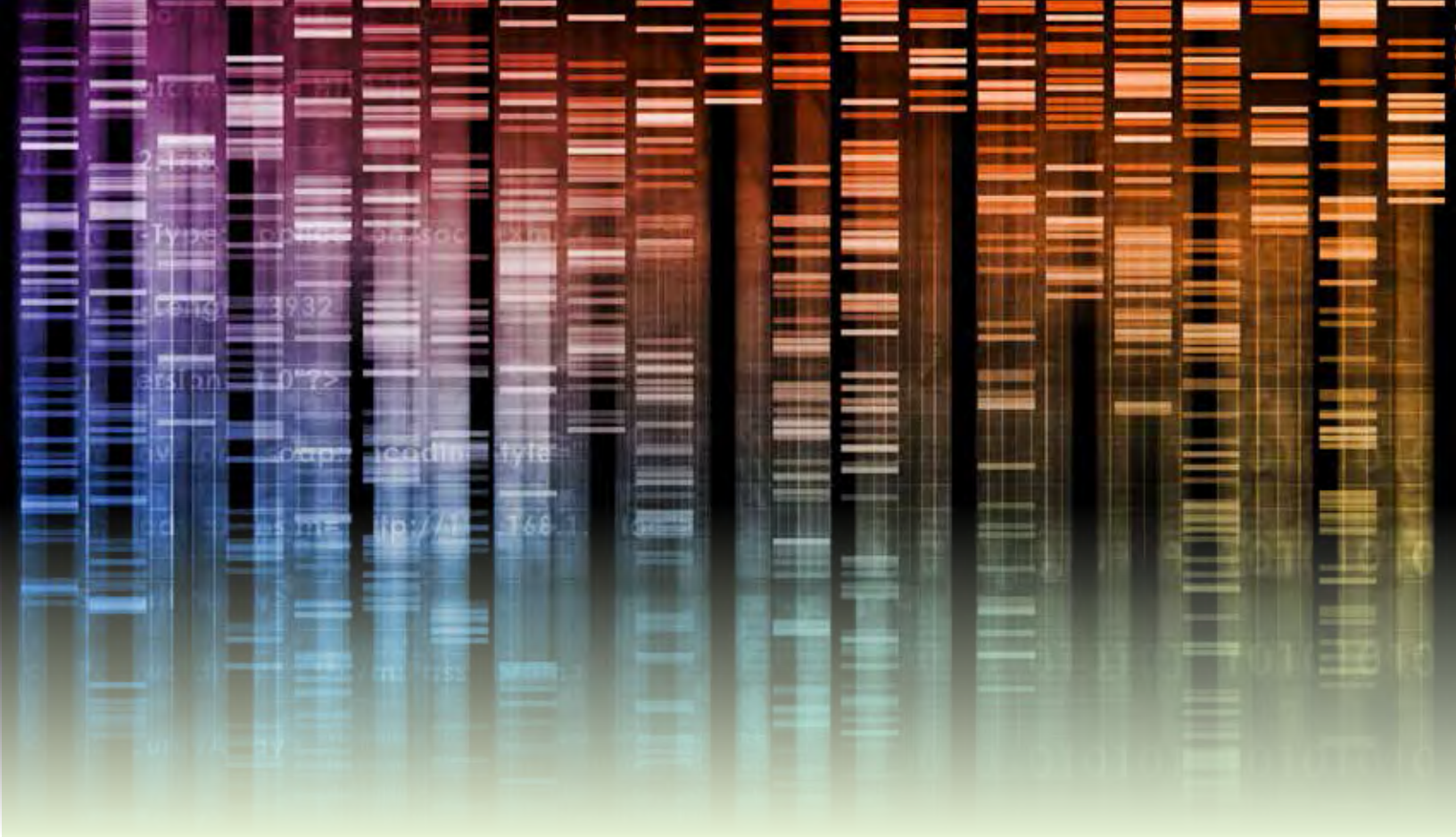
Goals: To promote a commitment to change in the undergraduate biology curriculum and to engage the biology community in the implementation of that change.

Project Overview: The California State University (CSU) Program for Education and Research in Biotechnology (CSUPERB) is a systemwide faculty network that involves and supports over 300 faculty each year and operates as a large community of interest and practice. The network involves over 650 students and faculty annually in a variety of departments at all 23 CSU campuses. CSUPERB cannot stretch to support all CSU biology students or faculty, so any systemwide impact and change that it has depends on commitments from campus-based change agents, leaders, and external organizations.

Methods and Strategies: CSUPERB outlined a new strategy to support "high-impact" educational practices, such as learning communities, service learning, and undergraduate research, that deepen learning, improve student continuation in STEM, and close achievement gaps. The two primary tactics are to administer seed-grant programs and to organize faculty-led professional development workshops, meetings, and conference sessions.

Evaluation: Final reports, participant surveys, and long-term reports assess whether the network is effecting change. Data are collected and analyzed to identify the numbers of students involved in CSUPERB-supported activities and to measure outcomes (retention in a degree program, graduation rates, postgraduate placements), ascertain levels of faculty and administrator participation in CSUPERB-organized workshops, and sustain the implementation of seed-grant–funded evidence-based teaching and learning practices in biology departments.

Impacts to Date: Since 2008, CSUPERB has increased funding for student research by 47%, supporting 506 students in faculty-led research groups across California in 2011–2012 alone. CSUPERB student graduation rates are greater than 80% across all demographics,



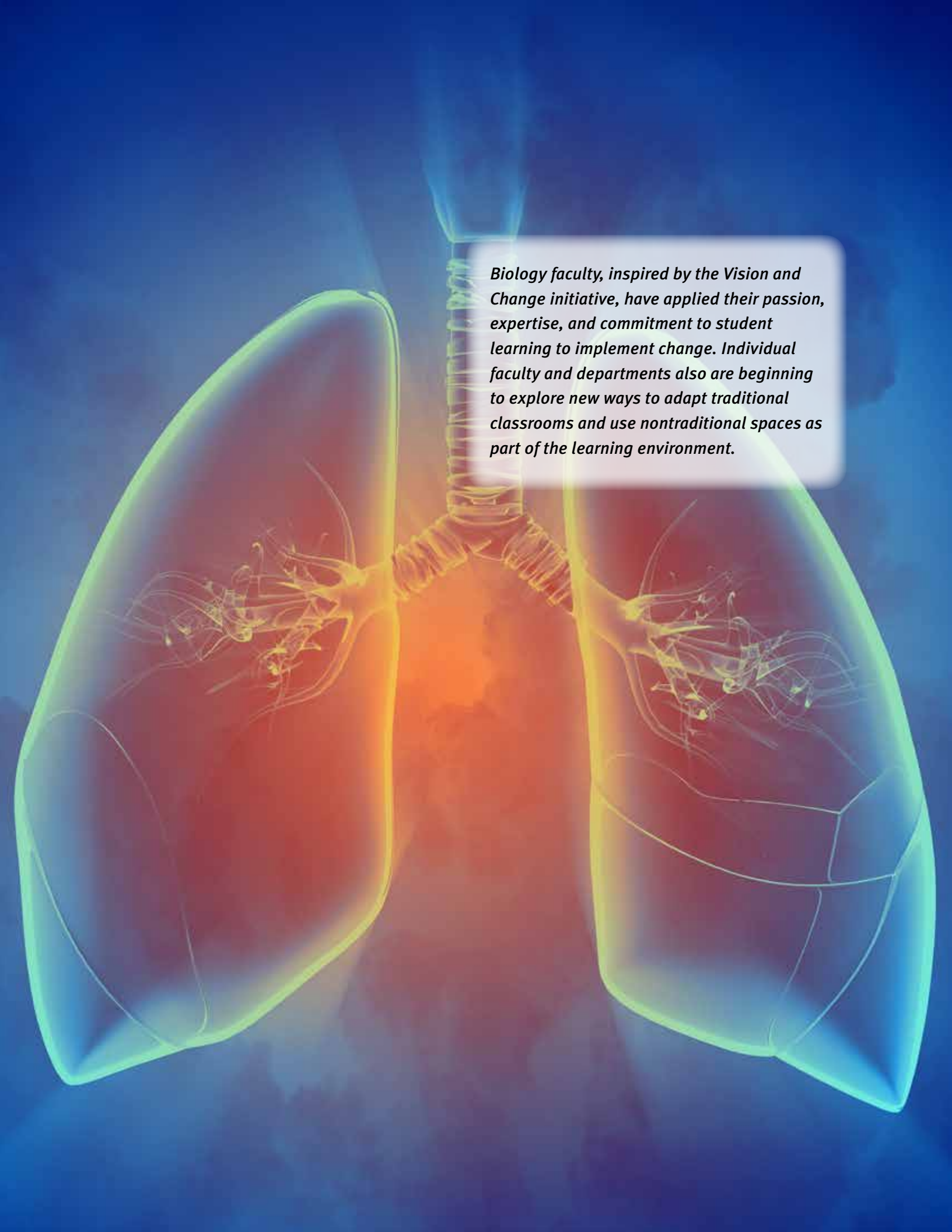
far exceeding average CSU STEM six-year graduation rates (28% for students entering the university in 2002). Eighty percent of CSUPERB-supported students continue in life science career paths, accepting jobs in the life science industry or entering graduate school programs. CSU faculty mentors retained 91% of CSUPERB-supported summer researchers during the academic year, suggesting that student engagement is assured.

Unexpected Challenges: Challenges include faculty unwillingness to recruit "at-risk" students into their laboratories or community-based projects, lack of commitment to evidence-based teaching and learning, and the vexing California budget crisis.

Impacts to Date: Although it is too early to assess the impact of CSUPERB, practices reported by 15 of the 23 campuses involved in the network include student-centered or "flipped" classrooms, computational or genomics project-based labs, and multiple modes of learning in high-enrollment and introductory biotechnology-related courses. The reports suggest that Vision and Change recommendations to create active-learning environments are gaining traction and adoption; however, intentional, coordinated departmental efforts are not yet the norm.

Dissemination: CSUPERB issues annual reports located on its website, organizes an annual systemwide biotechnology symposium, and sponsors professional development opportunities for faculty throughout CSU.

Acknowledgments: Ken O'Donnell, senior director, Student Engagement and Academic Initiatives and Partnerships, and Judy Botelho, director, Center for Community Engagement, CSU Office of the Chancellor; Koni Stone, professor, chemistry, CSU Stanislaus; Michael Goldman, professor, biology, San Francisco State University; Katherine McReynolds, associate professor, chemistry, CSU Sacramento; grant funding from the W. M. Keck Foundation (Association of American Colleges and Universities' Project Kaleidoscope).



Biology faculty, inspired by the Vision and Change initiative, have applied their passion, expertise, and commitment to student learning to implement change. Individual faculty and departments also are beginning to explore new ways to adapt traditional classrooms and use nontraditional spaces as part of the learning environment.

CHAPTER 2

CHRONICLING CHANGE

As part of their working group assignments, conference participants responded to a series of overarching questions that helped define the impact to date of the Vision and Change initiative on their own campuses and at institutions nationwide. This chapter provides an overview of their responses, ranging from specific institutionwide changes already implemented to the challenges faculty still face when trying to improve the way undergraduate biology is taught.

ACCOMPLISHMENTS SINCE 2009

Most meeting participants agreed that, since the original Vision and Change meeting in 2009, undergraduate biology education has improved at a number of institutions. As part of their discussions, working groups reported that more college and university administrators are championing and implementing change efforts, often at their own expense (i.e., not relying on external grant funding), and are beginning to understand the impact that reformed courses can have on retention. Moreover, the core concepts and competencies presented in the original Vision and Change report now influence the way many departments initiate discussions about their curricula. Other accomplishments include the following:

- Biology undergraduates are participating in authentic research and publishing in peer-reviewed journals.
- More faculty are conducting biology education research, and campuses are hiring more discipline-based education research faculty.
- Active learning is no longer a novelty, but rather an expectation.
- The undergraduate biology education community now includes social scientists, evaluation experts, and education scholars.
- Concept inventories and multiple other types of assessments are used to inform faculty as they change their teaching methods and to document student-learning outcomes.

DRIVERS OF CHANGE

Many factors have contributed to the progress made to date. Biology faculty, inspired by the Vision and Change initiative, have applied their passion, expertise, and commitment to student learning to implement change. Individual faculty and departments also are beginning to explore new ways to adapt traditional classrooms and use nontraditional spaces as part of the learning environment. In addition, adjunct faculty and graduate instructors committed to Vision and Change goals have helped advance undergraduate biology education specifically and STEM teaching and learning more broadly. Among other drivers of change over the last four years are the following:

- The original Vision and Change report has created a common language and blueprint for changing the way undergraduate biology is taught.
- Senior administrators, including department chairs, provosts, and deans, are beginning to see their vested interest in supporting and sustaining change at the departmental and institutional level.
- More admissions offices acknowledge that improvements to the teaching and learning of biology and other STEM fields can help with recruitment.

- Biology and other departments are changing the way they evaluate faculty, encouraging more life sciences faculty to invest time in improving their teaching.
- External funding agencies are supporting the introduction of improved approaches to undergraduate biology curricula and classroom practice.

METRICS OF CHANGE

Although not yet readily available at a national level, several indicators could and should be collected to measure the impact of the Vision and Change initiative not only on undergraduate biology education but on other STEM fields as well. For example, evidence of improved student learning and of increased rates of retention and graduation for biology majors would help convince others to make changes in how all STEM disciplines are introduced and taught at the undergraduate level. Additional metrics of improved undergraduate biology education suggested by meeting participants include the following:

- The number of undergraduate biology programs that have incorporated the core concepts and competencies from the original Vision and Change report.
- Improved student retention rates in biology majors and increased learning both in class and after completion of the course or graduation from the school.
- Changes in institutional goals, leadership, and incentives, such as promotion and tenure, in support of improving faculty teaching and student learning in STEM.
- Increases in the number of professional associations promoting initiatives that lead to greater attention to undergraduate student learning in biology, such as promoting discussion sections at national meetings, highlighting effective approaches, and helping with the scaling up of these projects nationwide.
- Changes to the physical infrastructure of a school, including classroom repurposing and/or redesign, to accommodate more active learning.

SCALING CHANGE BEYOND THE CLASSROOM

Conference participants pointed to several methods for scaling up the Vision and Change recommendations beyond the individual classrooms in which they were first introduced. For example, a clearinghouse of projects and programs would make it easier for faculty, departments, and institutions to see what practices and assessments are being used, and for what purposes, around the country. Such a centralized clearinghouse might also include an overview of specific educational goals to enable comparisons of students across institutions. Among other suggested methods for scaling up the impact of Vision and Change recommendations were the following:

- Increasing networking at all levels, to include students, advisers, faculty, administrators, and centers for teaching and learning.
- Building more cross-institutional collaborations and networking across higher education institutions of all types, including two-year colleges and private and public campuses.
- Supporting reformed courses and enhancing CourseSource and PULSE outreach.
- Emphasizing the importance of undergraduate education in professional society national meetings.
- Encouraging corporate sponsors and other large donors to invest in more collaborative learning spaces on campuses.

OTHER OBSERVATIONS AND TOOLS

Participants often had wide-ranging discussions that ventured beyond the overarching and specific thematic questions. For example, they made general observations about the process of improving undergraduate biology education and, as they looked to the future, made recommendations for other tools needed to continue advancing the Vision and Change initiative nationwide. Some of their recommendations were as follows:

- The biology community needs to get beyond its disciplinary "silos," transfer change efforts to other STEM colleagues, and identify teaching and learning advances in other departments.
- As biology becomes more interdisciplinary, so must undergraduate education efforts in STEM.
- Proponents of improving undergraduate biology education need to ensure that scholarly educational research is disseminated to all biology faculty.
- Faculty and administrators need a "go-to" site that includes sources of relevant literature, instruction on effective pedagogy, useful assessment tools, and resources to help design a new class or activity.
- Faculty development should focus on a broad spectrum of instructional staff, including early-career faculty and non-tenure-track faculty, such as adjuncts and lecturers.
- The biology community needs to invest in leadership development that is focused on student success and on academic leadership for change at colleges and universities. Partnerships with recognized faculty development/leadership institutes could be beneficial here.

- Faculty need support for experimentation and initial failure because transforming teaching can take time to develop and implement successfully.
- Advocates of change in undergraduate biology education need to be aware of, and responsive to, the needs, challenges, and contributions of diverse types of institutions.
- In addition to inspiring change at the individual faculty level, colleges and universities need to work to encourage departments to examine, discuss, and consider the effectiveness of STEM programs in light of student learning and engagement.
- Renovation of classrooms and teaching laboratories should be a priority at all institutions, with more thought going into how spaces are designed and used today (and will be used in the future) and how existing spaces can become more inclusive, inviting, and engaging learning environments.
- More research is needed into the use of virtual space and communications, and the impact they have on faculty–student interactions and learning.
- More creative ways are needed to assess course transformations that go beyond student perceptions of the course and focus instead on course goals and whether or not students accomplished them.

INTERDISCIPLINARY SCIENCE WORKSHOP FOR INCOMING STUDENTS

Anne Kruchten, Associate Professor and Chair, Biology, Linfield College, Oregon

Goals: To help biology students discover the interdisciplinary nature of science and to enhance their ability to communicate and collaborate with other disciplines as recommended by Vision and Change.

Project Overview: Faculty in the biology, chemistry, mathematics, and physics departments designed a weeklong workshop to immerse incoming students in an interdisciplinary, collaborative learning environment before classes started. In the fall of 2012, the Interdisciplinary First-Year Orientation Camp for Undergraduate Sciences (iFOCUS) engaged 10 new students in an authentic, collaborative research project with faculty representing multiple STEM disciplines. This program helps both faculty and students in STEM disciplines recognize the inherent similarities of the practice of science across disciplines, models interdisciplinary collaborations and communication, and fosters relationships and problem-solving skills among students and faculty.

Methods and Strategies: The iFOCUS program engages approximately 10 to 15 incoming students to help them develop relationships and to begin to establish an interdisciplinary science community. Students have opportunities to participate in interdisciplinary research projects, gain hands-on experience with laboratory and field techniques, and engage with student peer mentors.

Evaluation: Student and faculty evaluation forms suggest significant progress toward the goals of modeling interdisciplinary collaborations and communication and of fostering relationships and problem-solving skills among students in the STEM disciplines. Following their iFOCUS experience, 7 of the 10 student participants in the program in 2012 joined research laboratories during their first semester on campus. In addition, iFOCUS originally included 3 faculty participants, but 10 faculty members ultimately participated in the project.

Impacts to Date: Both the president and vice-president for academic affairs provide financial support for the iFOCUS program, support faculty planners' participation in Project Kaleidoscope and other workshops, and encourage a trustee initiative to raise funds to support innovative STEM programs at the college. By modeling effective scientific practices and developing an interdisciplinary STEM community, headway is being made toward achieving the aims of the Vision and Change call to action and toward engaging previously disinterested faculty.

Unexpected Challenges: Recruiting students can be a challenge. To reach more students, the second iteration of iFOCUS will continue the program experience by using learning communities. These communities will focus on problem-solving skills, such as participating in interinstitutional mathematics competitions and in the annotation of genome sequences carried out in conjunction with the Genomics Education Partnership, headed by Sarah Elgin of Washington University in St. Louis. Participants from iFOCUS will form the core of these learning communities and recruit other students to join them.

Dissemination: A manuscript summarizing the project will be submitted after the 2013–2014 program is complete. In addition, results will be disseminated to faculty from across Oregon and the Pacific Northwest who teach introductory biology courses.

Acknowledgments: Thanks go to President Thomas Hellie of Linfield College, and to the college itself, for continued financial support of the iFOCUS program.

COLLABORATION AND REFORM AT THE UNIVERSITY OF TENNESSEE

Elisabeth E. Schussler, Assistant Professor, and Anna Jo Auerbach, Graduate Student, University of Tennessee, Knoxville

Goal: To transform the core curriculum for biology majors at the University of Tennessee–Knoxville so that it focuses more explicitly on the process of science.

Project Overview: In 2010, the University of Tennessee (UT)–Knoxville's Division of Biology formed a faculty task force to consider how to integrate the principles set forth in Vision and Change into the curriculum. That process resulted in a plan to restructure the first-year biology majors' sequence at UT. The plan was near-unanimously approved by the biology faculty after a careful process of vetting ideas, gathering feedback, and modifying details over a period of two years. With a heavy reliance on Vision and Change to justify and direct the changes involved, collaboration and compromise ultimately led to a consensus.

Methods and Strategies: The biology division combined Vision and Change concepts and competencies with active learning into a revised two-semester cellular–organismal sequence, integrated small-group discussion sections into the courses, and refocused the labs on the process of science. Instructors monitored these changes and met regularly to create implementation strategies. All classes were planned around the concepts, competencies, and associated activities, with discussion sections and an independent lab added in the second year. Graduate students, undergraduates, and postdocs participated in the creation of the discussion curricula, which focused on an examination of primary literature.

Evaluation: Short online questions ask students to explain a cellular/molecular and an organismal/ecological aspect of each of the five Vision and Change concepts. Laboratory outcomes are being assessed by student self-reports, as well as by the Test of Scientific Literacy Skills (TOSLS; Gormally, Brickman, & Lutz, 2012). Student responses to the "most important thing" they learned in the courses are being evaluated to see whether Vision and Change concepts are being mentioned. Finally, and perhaps most importantly, the process of change is being documented at the faculty and course levels. Class observations to assess the frequency and length of active-learning methods have continued throughout the transition from the old to the new curriculum. Faculty have volunteered to be interviewed each semester and are providing course materials for analysis.

Impacts to Date: Institutionally, the changes have been used as an exemplar of curricular transformation, and they resulted in a collegewide teaching award for Professor Schussler, who copresented an active-learning training session for department heads. Vision and Change concepts and competencies have been adopted as learning outcomes for the entire biology division for the purposes of the Southern Association of Colleges and Schools (SACS) assessment. Class observations found a programmatic average of 28% of class time utilizing active learning in 2012–2013 and 25% in 2013–2014. Observations in fall 2014 recorded an active-learning average of 33%, despite a one-third reduction in lecture time to add small-group discussion classes. The curriculum changes also inspired an NSF research coordination network incubator Biology Teaching Assistant Project to focus on developing instructional skills for graduate teaching assistants teaching reformed courses.

Unexpected Challenges: Everyone who teaches the introductory courses has been willing to share course materials, but finding a virtual location to gather those materials (and transferring them there) has been difficult. Another challenge has been fear of trying new

things. Faculty need very specific strategies they can use, because they are reluctant to create their own materials. Existing assignments and active-learning activities are being shared, and faculty are encouraged to use or modify them for their own classes. Classroom visits are also encouraged for faculty to see the materials in action. Finally, some have expressed resistance to reducing course content, but this challenge was not unexpected.

Dissemination: Information about evaluation strategies, the evolution of course changes over time, and faculty reaction has been disseminated at individual institutions and national meetings of professional societies. A website has been created for the graduate teaching assistant professional development project (www.bio.utk.edu/BioTAP) so that progress can be reported and the names of faculty who want to join the network can be gathered.

Acknowledgments: This project has been supported by an NSF TUES grant (DUE-1245215), an RCN–UBE Incubator award (DBI-1247938), and the faculty and graduate and undergraduate students of the Division of Biology at the University of Tennessee.

CLASS STRATEGIES FOR INCREASING ACHIEVEMENT OF ALL STUDENTS

Sarah Eddy, Research Associate,Sara Brownell, Research Associate, Mary Pat Wenderoth, Principal Lecturer, Alison Crowe, Senior Lecturer, and Scott Freeman, Senior Lecturer, University of Washington, Seattle, Washington

Goals: To increase the retention and achievement of all students (particularly those from historically underrepresented groups) and to provide students with opportunities to develop skills aligned with the core set of concepts and competencies suggested by Vision and Change.

Project Overview: The University of Washington developed an introductory biology course that includes daily quizzes to encourage students to prepare for class, an almost exclusively active classroom in which students work on questions at higher cognitive levels, and weekly practice exams to provide students with questions and opportunities to review course material.

Methods and Strategies: The active classroom involves clicker-based activities following the peer-instruction model, small-group discussion questions whereby the instructor calls on students by name to encourage participation, and longer worksheet-based activities.

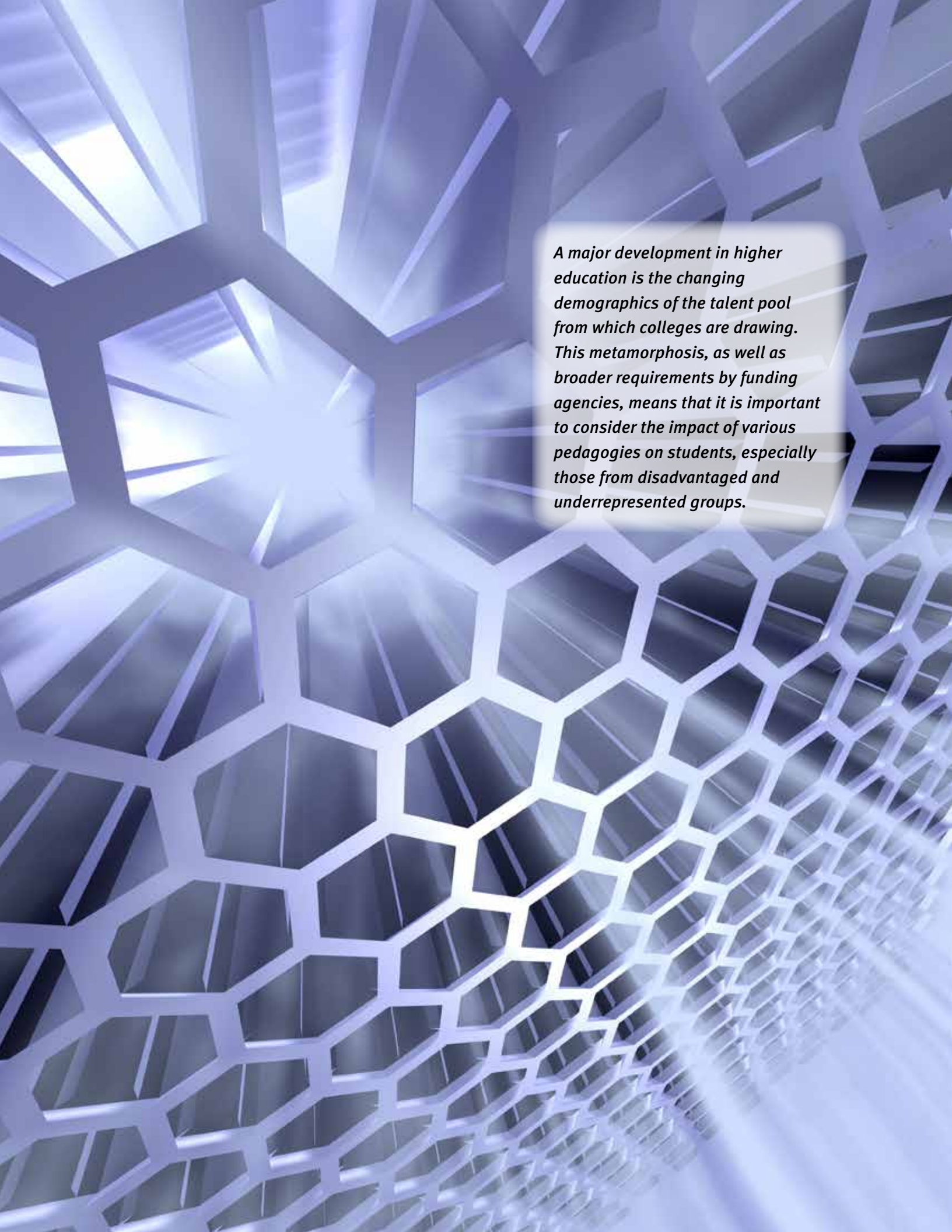
Evaluation: Changes in the course were evaluated with student exam points and final course grades after controlling for student academic ability. Impacts of the transformed course on students from historically underrepresented groups also were evaluated, and students were followed through the next two courses in the series, taught in a more traditional manner, to determine how students who passed the more highly structured active-learning course fared in a more traditional lecture classroom. In addition, researchers identified five concepts that students found particularly challenging: natural selection, climate change, Hardy–Weinberg equilibrium, experimental design, and tree thinking (i.e., understanding evolutionary relationships). The researchers developed two worksheets for each concept, using a different approach to build student understanding and to help identify which approach was most effective for student learning.

Results to Date: Changing from a traditional lecture course to a more highly structured active-learning course decreased the failure rate from 18% to 6%, increased student performance on exams, and closed the achievement gap between educationally or economically disadvantaged students and the other students by 45%, resulting in more students (particularly underrepresented ones) able to continue in the major. Furthermore, students who had been predicted to fail a traditionally taught first course not only passed the refashioned version, but continued to be successful in subsequent courses. It appears that, once students get a core set of skills, they are able to be competitive in the major. Performance data that validate both the course structure and the activities undertaken therein afford a strong argument for the adoption of these practices. All instructors teaching this course and the follow-on introductory courses have adopted the reading quizzes and practice exams, as well as many of the in-class activities.

Unexpected Challenges: The major challenge has been fidelity of implementation—that is, faculty using some parts of the reformed course format but not all of it. To address this challenge, the research group has developed (1) a classroom observation tool that quantifies fidelity to three elements of reformed courses: providing practice, creating accountability, and developing scientific-thinking skills; (2) a mentoring program for postdoctoral fellows who teach in the series; and (3) a facultywide review of the entire introductory series—a review that emphasizes fidelity and consistency. A curriculum assessment tool aligned with Vision and Change is also being developed.

Dissemination: In addition to presenting papers at conferences and publishing research results (see, e.g., Freeman et al., *CBE Life Sciences Education,* 2011), project leaders are developing a video series for the Internet describing how to implement a high-structure, active-learning course; research-based activities for introductory biology are also being developed to help faculty implement an active-learning course.

Acknowledgments: This project was supported by NSF DUE (#1118890 and #0942215), the Howard Hughes Medical Institute (grant 52003841), and the College of Arts and Sciences and Department of Biology, University of Washington.



A major development in higher education is the changing demographics of the talent pool from which colleges are drawing. This metamorphosis, as well as broader requirements by funding agencies, means that it is important to consider the impact of various pedagogies on students, especially those from disadvantaged and underrepresented groups.

CHAPTER 3

INSPIRING THE FUTURE

Although the 2013 Vision and Change conference included plenary sessions, panel discussions, and poster sessions, meeting participants spent most of their time in working groups. In these breakout sessions, participants highlighted what had been accomplished to date in advancing the Vision and Change initiative at their institutions and beyond, and identified what more needed to be done. This final chapter provides an overview of group discussions and their road maps for further action.

LEADING CHANGE

Institutional policies can help create a context for change. For example, when a department requests funds to support curricular changes, institutional policy can require assessment and other documentation of changes made to improve undergraduate biology education. If teaching innovation and student success are stated as desired outcomes, then departments and campuses should create faculty and staff rewards and other special recognitions as part of their professional advancement programs to help facilitate change.

Students who aspire to a career in biology or another STEM field require a strong foundation in biology. Programs that increase the potential for undergraduate biology students to persist in their studies until graduation can help ensure that students develop the skills they will need to work as a scientist, as can programs that present science as an exciting, evolving process of discovery rather than a repository of facts. Achieving these kinds of changes requires that everyone committed to student success work together and that their efforts align at all levels within the institution and across all STEM disciplines.

Improving undergraduate biology education involves more than just altering curricula and teaching approaches, however: Good advising and mentoring can improve retention of students, and opportunities for peer interactions can promote a sense of community that fosters retention. Moreover, interdisciplinary education and cocurricular activities can promote student success. Administrators and faculty alike need to recognize the important role that advising plays in improving the undergraduate student experience and, toward that end, need to provide multiple opportunities for peer interactions (e.g., summer bridge programs, freshman learning communities, peer mentors, supplemental instruction, science cafés for high school students) to foster a sense of community. Students also need more opportunities to engage in interdisciplinary thinking.

Finally, as stated earlier—and one of the main thrusts of this document—real change requires leadership at all levels, from administrators and faculty to postdoctoral fellows and graduate students. Some campuses even engage undergraduates to provide the formative feedback needed to develop better course materials. Embedding the expectation of leadership throughout the culture of the academy helps develop and empower a collaborative group of visionary undergraduate biology education leaders.

ROAD MAP

Policy and Change

- Develop mission statements and business plans that reflect the full impact of changing existing policies and the resources required to implement them, including plans for assessing new learning objectives.

- Build campus coalitions of faculty and other classroom instructors, administrators, and students (both graduate and undergraduate) to help initiate and implement successful change in undergraduate biology.
- Continue to include science education scholarship at professional society meetings and in discipline-based journals, and incorporate Vision and Change principles into certification programs.
- Engage in more national conversations such as Vision and Change to encourage more undergraduate institutions to become committed to improving undergraduate biology education and STEM education in general.

Cultivating Educational Leaders

- Raise awareness about the importance of leadership, work with professional societies on leadership issues, and articulate expectations for success.
- Work to ensure that institutions reward leadership, provide opportunities for faculty to explore alternative practices (e.g., through fellowships), and develop an explicit plan to empower future leaders.
- Build collaborative teams to identify and develop graduate leadership-training opportunities, engage with departmental hiring decisions, serve on relevant committees, and participate in annual evaluations.
- Demonstrate innovative, transformational, and evidence-based teaching practices, and new evaluation criteria developed for hiring, promotion, and tenure.

Student Access and Retention

- Promote an increased desire for success in students and for better learning outcomes.
- Work to ensure that incentives and resources are available for the highest quality of advising, data collection and use, and interdisciplinary learning opportunities.
- Eliminate the institutional barriers that discourage interdisciplinary learning opportunities and cooperation between departments.

Creating Movements for Change

- Build on the existing Vision and Change momentum, duplicating the model of regional meetings followed by a national conference.
- Establish a national conference series similar to Vision and Change that features case studies (i.e., levers) and includes individuals working at department-, college-, and institutionwide levels (i.e., scales) and in different disciplines.
- Create a mechanism for writing up success stories from the meetings and reporting them in a prestigious national journal.

HELPING FACULTY BECOME AGENTS OF CHANGE

The recommendations outlined in Vision and Change have initiated new, inspirational pedagogies and curricula, and changed the way many students learn biology. More students now experience authentic or novel research experiences and semester-long research labs, and spend less time in traditional classrooms. For many faculty, however, making significant changes in how they teach involves risk taking and a major commitment of time. Providing support to faculty as they explore new approaches and rewarding their success can help encourage change. For example, creating more financial and professional opportunities to acknowledge faculty and institutional success in improving undergraduate biology teaching and learning can motivate change, as can developing a mechanism to recognize quality teaching and successful departments as they work to improve the teaching and learning of undergraduate biology.

One of the more challenging discussions at the 2009 Vision and Change national conference was defining how to end the depth-vs.-breadth argument in undergraduate biology education. Success may lie in changing the conversation to critical thinking vs. factual recall. As the new approaches to teaching and learning are implemented, all instructional staff will require additional access to quality professional development. Such access can be achieved in part by fostering the building of community around the goal of improving undergraduate biology education, but it also calls for the furtherance of professional development tailored to the specific needs of graduate students, instructors, and faculty.

ROAD MAP

Encouraging Change

- Work on developing an institutional culture that emphasizes the importance of teaching and learning.
- Use the Vision and Change recommendations as a blueprint for improving undergraduate biology education.
- Continue to support transformative activities on campus to encourage change.
- Develop national mechanisms for recognizing achievements in improving teaching and learning and the successful implementation of effective practices in advancing undergraduate biology education.
- Promote special editions and sections in scientific journals to alert scientists to changes taking place, as well as feature overviews of innovative practices that promote teaching and learning as a form of recognition and accomplishment.

Professional Development

- Connect faculty with campus-based centers to promote even more effective teaching and learning.
- Identify and articulate different professional development solutions for different groups.
- Establish internship exchange programs and invite teaching and learning experts to give presentations and interact with campus faculty and administrators.
- Provide iterative, face-to-face professional development opportunities for all instructional staff, from graduate students to senior faculty.
- Create opportunities for peer reciprocal observation feedback, with no promotion or tenure stakes involved. Also, colleges and universities should develop protocols for these kinds of college-level teaching observations.

Faculty as Agents of Change

- Create more opportunities for faculty professional development.
- Develop teaching rubrics to help faculty recognize the need for student-centered teaching.
- Support institutional and regional communities of practice, especially around assessment.

CHANGING THE STUDENT EXPERIENCE

A major development in higher education is the changing demographics of the talent pool from which colleges are drawing. This metamorphosis, as well as broader requirements by funding agencies, means that it is important to consider the impact of various pedagogies on students, especially those from disadvantaged and underrepresented groups. Research is emerging that underscores the positive effects of active learning on all students. For example, including authentic research in undergraduate biology education, particularly when the research explores issues or questions relevant to students, can enhance student understanding of both the science itself and the scientific process.

To this end, biology faculty need more opportunities to learn about best practices and methods for introducing discovery-based approaches to research into the undergraduate biology classroom and more needs to be done to highlight best practices and case studies and to bring national recognition to those promoting the use of authentic research in their classrooms. Most campuses also can benefit from additional outreach, recruitment efforts, and financial and other support (e.g., mentoring) to broaden the participation and success of more students in biology curricula.

As faculty and other instructional staff have explored new methods of teaching, many have discovered that the physical classroom itself can improve student experiences and assist with learning. Even small changes, such as the ability to move chairs closer together in smaller discussion groups, can have a big impact, as can using spaces outside the physical classroom as potential learning environments. Because the classroom environment can affect teaching and learning, faculty and administrators need more opportunities to master the relationships between physical space, on the one hand, and teaching approaches and learning goals, on the other.

ROAD MAP

Broadening Participation

- Make more seed funding (both external and internal) available to support small, focused projects to help increase the participation of underrepresented groups in biology classes.
- Collect and disseminate evaluation data from projects to help convince faculty and administrators that these new initiatives are successful.

Offering Authentic Research Experiences

- Develop a national clearinghouse of best practices and case studies to showcase successful classroom techniques and bring national recognition to those promoting the use of authentic research in their classrooms.
- Provide examples of the kinds of research being incorporated into student laboratories and of outcomes from that research, including results published in peer-reviewed journals.
- Provide examples of research being done concerning how engaging in authentic research might enhance undergraduate biology education and how other effects of engaging students in authentic research (e.g., student understanding of key concepts, development of essential skills, and understanding of the ways of science) might be captured and evaluated.

- Disseminate relevant and validated methods of assessing short- and long-term gains in learning outcomes and student understanding of STEM in general.

Creating Appropriate Physical Spaces for Learning

- Increase awareness of best practices for designing new and remodeled space, as well as innovative approaches for using existing space.
- Involve STEM faculty in planning and in making decisions about the design and use of space.
- Provide wider dissemination of available research about design and use of the classroom.

BUILDING NETWORKS FOR CHANGE

By sharing best practices and lessons learned, networks increase buy-in and reduce the cost of failure while providing opportunities for new members (e.g., students, administrators, new faculty) to join an active community dedicated to improving undergraduate education in biology. Networks also help faculty, students, and interdisciplinary teams build communities of interest outside their campus.

Networks facilitate opportunities for face-to-face interaction and lead beyond data collection to empower people to act on findings. As important is the fact that connecting existing networks can result in new interactions across the networks and enlist new supporters of improving undergraduate biology education.

In addition to disseminating curricula, tools, and assessments, networks help support scaling of projects and encourage research in science education. Moreover, because of their dynamic nature, networks can evolve and have spin-offs, although they may also become extinct.

ROAD MAP

National Alliances

- Create Wikipedia entries for “Vision and Change” and “Biology Education Networks,” and an online registry for existing networks that is searchable by location and purpose.
- Connect PULSE profiles with other networks (e.g., by using the keyword “Vision and Change”), and identify mechanisms for evaluating the profiles.
- Support those networks dedicated to improving undergraduate education and success in biology and other STEM disciplines.
- Push for more education articles in research journals, and connect a database of biology education research articles with education research articles from social and behavioral science journals. The new database of articles could be linked in with the journal *CourseSource* at the University of Minnesota.

Collaboration

- Identify relevant networks (e.g., PULSE) dedicated to the goals of the Vision and Change initiative, and disseminate the information they contain.
- Compile, synthesize, and share with colleagues literature on organizational change and network science through the networks identified in the previous bulleted item.
- Continue holding national meetings, such as Vision and Change, as a way to enhance collaboration.
- Support professional development and leadership training for network leaders.

AMASSING EVIDENCE OF CHANGE AND ITS EFFECTS

Faculty routinely incorporate assessments into their teaching. However, they still may fail to recognize that assessment can provide feedback on how well students are understanding concepts and developing skills. Moreover, they may not know how to use the information gleaned from assessments so as to improve their instruction, even though there is a growing emphasis on scholarly teaching and assessment resources are available to assist in improving instruction. The existence of these resources and how to access and best use them is not always apparent to the broad spectrum of faculty who could benefit from their use.

Undergraduate biology educators now have increased access to effective teaching strategies thanks to an emerging collection of assessment tools, program designs, and institutional efforts. Moreover, Vision and Change has helped elevate the importance of assessment and evaluation within the biology community and beyond, and has increased awareness that both assessment and evaluation are critical to being a successful life science educator. For more widespread change to take place, however, faculty and administrators need additional opportunities to learn about the importance of assessment and evaluation, as well as about effective methods of carrying out these tasks. Also, conducting and disseminating longitudinal research on effective approaches to improving undergraduate biology education will help gain wider support for those approaches.

In addition, the undergraduate biology education community requires expert online resources for assessing evidence of change. Such an interactive web-based portal should include student learning outcomes and faculty teaching practices and behaviors. For example, PULSE is gathering online assessment and evaluation examples and resources so that a broad spectrum of the STEM community can learn how to better assess change in their classrooms and programs.

ROAD MAP

General Biology Education

- Adopt student-centered teaching approaches in classrooms and laboratories, starting from well-defined learning outcomes that are measured with the use of appropriate assessment instruments.
- Develop an accessible repository of validated assessment and evaluation tools that can be used for cross-institutional studies, curriculum development, collaborative research, and the sharing of results. Such a repository can help to identify quality information, research data, and potential collaborators and mentors.
- Encourage professional societies to develop a national plan for establishing standards for undergraduate biology teaching, and enlist the support of administrators and department chairs to realize the plan.

Assessment

- Provide faculty with information about vetted assessment methods, including instructions on how to use them to help inform and direct changes in teaching.
- Align assessment and other tools with general institutional education goals.
- Encourage life science faculty and education researchers to collaborate to advance evidenced-based teaching across multiple levels.
- Ensure that research on teaching efforts—particularly efforts aimed at developing assessments—includes a broad spectrum of students and that the data are disaggregated so that variations among student groups can be ascertained.
- Create a curated and moderated clearinghouse of assessment tools to encourage collaboration between education researchers and biology faculty.

- Provide faculty, postdocs, and graduate students with access to leadership training and professional development to encourage a culture that values assessment as a crucial component of undergraduate teaching.

Evidence of Change

- Articulate the value of assessment to all stakeholders, including students, faculty, administrators, and the general public.
- Develop an online resource with the tools needed to help faculty and administrators assess evidence of change.
- Conduct active outreach efforts to explain the necessity and benefits of constant assessment to help guide change efforts.

CURRICULAR ASSESSMENT AND REVISION AT A MILITARY SERVICE ACADEMY

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Goal: To provide a modern, rigorous program in the biological sciences while meeting the institutional mission of preparing future officers for the U.S. Air Force.

Project Overview: The Department of Biology at the U.S. Air Force Academy (USAFA) viewed the publication of *Vision and Change in Undergraduate Biology Education* as an opportunity to assess the department's success in meeting departmental and institutional goals and to consider improvements to the curriculum. The evaluation began as a self-study that compared Vision and Change core concepts and competencies with departmental goals for knowledge, skills, attitudes, and values, and then transferred those findings into departmental teaching and learning goals.

Methods and Strategies: An *ad hoc* curriculum task force with representative faculty compared the existing USAFA biology curriculum with the recommendations of the Vision and Change report. The task force then consolidated the collected opinions of faculty from small-group discussions and formulated a series of options for curricular change. A second task force created new learning goals that incorporated the Vision and Change recommendations while acknowledging the unique USAFA goals pertaining to attitudes and values, departmental constraints (e.g., fiscal and manpower constraints), and the need for faculty agreement. Using large and small discussion groups, online reviews of proposed changes, and the sharing of iterative results, the task force created new goals that were approved by the entire department.

Evaluation: Assessment consisted of a progressive series of self-evaluations, strategy sessions, and implementation plans. The Curriculum Task Force report was initially met with significant resistance. Although task force members solicited input during their deliberations, many faculty members were reluctant to share their concerns when the entire department was assembled. Over the course of multiple departmental meetings and informal one-on-one exchanges, specific objections were gradually brought into the open and overcome.

Impacts to Date: Applying core concepts to the content of individual biology courses produced more cross-course coverage than the subject-based conceptual knowledge of the original learning goals. It also allowed the department to synchronize learning goals with broader institutional outcomes. These revamped goals now specifically address quantitative reasoning and simulation/modeling within both biology courses and the broader USAFA core curriculum. The new goals include having faculty teach, and students learn, "Core Concepts for Biological Literacy," "Core Competencies and Disciplinary Practices," and "Core Attitudes and Values." Moreover, these goals remain consistent with the Academy's desired outcomes. The department is now in the process of aligning its curriculum with the new learning goals.

Unexpected Challenges: A challenge unique to the military service academies is the relatively high turnover of faculty. It is typical for officers to be limited to a three-year teaching rotation. Even senior officers are subject to transfer or occasional overseas deployment. Therefore, any plans for curricular revision are dependent largely on explicit documentation and the small number of more permanent civilian faculty members. Moreover, the curriculum must allow for the ever-changing disciplinary strengths that accompany each annual turnover of instructors. An additional challenge, probably shared with many undergraduate institutions, is the delicate balance between the needs of students majoring in biology and the rigorous demands on all students, regardless of major.

Dissemination: Revised departmental learning goals and expectations are being incorporated into the *Biology Majors' Handbook,* and each course will explicitly link course learning goals and outcomes to the department goals and expectations.

Acknowledgments: This project was supported in part by the Visiting Professor program at the U.S. Air Force Academy.

INFUSING QUANTITATIVE APPROACHES INTO THE UNDERGRADUATE BIOLOGY CURRICULUM

Katerina Thompson, Director, Undergraduate Research, University of Maryland

Goal: To infuse all levels of the undergraduate biological sciences curriculum with increased emphasis on interdisciplinary connections and quantitative reasoning.

Project Overview: This major curriculum redesign effort at the University of Maryland seeks to help students appreciate the essential role of mathematics and statistics in contemporary bioscience research and enable them to become more adept at applying their quantitative reasoning skills to biological problems.

Methods and Strategies: The major components of the program are (1) developing online modules to infuse more mathematical content into fundamental biology courses, (2) strengthening the interdisciplinary connections with ancillary courses in mathematics and physics to support the development of quantitative skills in biological contexts, and (3) creating more quantitatively intensive courses for the final two years of the biological sciences degree program. MathBench modules were designed to introduce or reinforce 10 basic quantitative skills identified by participating faculty as being important for competence in upper-level biology courses. Using an informal tone to encourage students to apply their

mathematical insights, these online modules gradually build in their level of mathematical sophistication. Interactive elements with contextually appropriate feedback are embedded throughout. A first-year student taking the entire required sequence of coursework would encounter about 20 of the modules over the course of his or her first two years.

Evaluation: The impact of MathBench on student learning and attitudes has been assessed with surveys and pre- and posttests of quantitative skill that use an instrument developed and validated specifically for this initiative.

Impacts to Date: Students who have used MathBench in their coursework show increases in quantitative skill that are independent of their previous math coursework. They also show an increase in their willingness to tackle quantitative problems and a better appreciation for the importance of mathematics to modern biology.

Unexpected Challenges: The greatest challenge has been assisting faculty in finding ways to incorporate MathBench modules into their teaching. Comprehensive training workshops help faculty create implementation plans and have established numerous ways of encouraging continued communications among MathBench users.

Dissemination: Project leaders are partnering with 32 U.S. institutions of differing types, sizes, and demographics to gather additional data on the effectiveness of MathBench modules in diverse educational contexts. As part of this process, the project has developed workshops to assist faculty with implementing the modules and has started to build a user community for peer support. More recently, a group of seven Australian universities expressed interest in collaborating on a grant-funded project to revise MathBench modules for the Australian educational context and assess their impact.

Acknowledgments: These projects were supported in part by grants to the University of Maryland from NSF (DUE 0735975 and DUE 1022938) and HHMI.

LEARNING SCIENCE BY WRITING: INTERDISCIPLINARY APPROACHES

Christine Hohmann, Associate Professor of Biology, Morgan State University, Ernest Steele and Stella Hargett, Morgan State University, and Julie Reynolds and Jason Dowd, Duke University

Goals: To engage students with the research-based literature; to enhance student literacy in biomedical and bioenvironmental concepts across STEM, including the social and behavioral sciences; to enable students to communicate across disciplinary borders; and to enhance student writing skills in preparation for graduate school and the biomedical workforce.

Project Overview: Morgan State University (MSU) has implemented an interdisciplinary, seminar-style, two-course writing curriculum within the larger context of a multi-institutional, NSF-funded study aimed at understanding the role of writing in promoting learning and engagement for diverse undergraduate thesis writers. This larger study, headed by Julie Reynolds at Duke University, focuses on understanding whether writing an undergraduate thesis improves critical thinking and writing skills by affecting metacognition, motivation, and/or beliefs, and whether these effects differ as a function of student characteristics and departmental context.

Methods and Strategies: Critical Analysis of the Research Literature (BIOL 450) and Senior Research Thesis (BIOL 451) use a student-centered approach in which the instructor serves primarily as moderator, with students engaged in focused discussions complemented by occasional minilectures given by a student or the instructor to explain discipline-specific concepts or terminology.

Evaluation: Pre- and postclass survey responses from all participants at the four collaborating institutions (MSU, Duke, the University of North Carolina, and the University of Minnesota) have been collected at Duke University. Two years of student theses sampled from all participating institutions have been rated with the Biology Thesis Assessment Protocol (BioTAP) scale, a teaching and assessment tool.

Impacts to Date: Evaluations suggested a substantial impact on students' scientific writing ability, resulting in as much as a 30% increase in students' abilities to effectively place their work in the context of current research in their field, among other benefits. Students rated these courses very highly (agree & strongly agree = 100% for BIOL 450 and >75% for BIOL 451) for enhancing their critical-thinking skills, in addition to increasing their research, writing, and oral presentation skills. The results also indicated weaknesses still remaining, resulting in the planned introduction of basic principles of the "scientific method," structural analysis of research papers, and extensive concept mapping of research papers to clarify relationships between background literature (what is known) and the research questions (the gaps in the literature being addressed). Data from the multi-institutional pre-and postsurveys also demonstrated increased self-confidence at the end of BIOL 451 across 11 of 15 categories assessed, although the small sample size precluded statistical significance. At the department and institutional levels, the sequence has helped open up the discussion arguing for curriculum change and the redesign of foundation and gatekeeper courses for biology majors in accordance with the recommendations of Vision and Change. The MSU Biology Department is currently one of eight pilot institutions undergoing review for the PULSE Community certification process.

Unexpected Challenges: Heavily scripted curricula in science disciplines leave little room for students to take additional electives. As part of the curriculum review process, the Department of Biology has redeveloped its curriculum to allow for more course choices, especially among upper-division courses. Students may now choose to take the more-research-focused BIOL 450 course in lieu of the previously mandatory "Scientific Communication" class.

Dissemination: Preliminary results of the multi-institutional study were presented in a poster at the American Association of Physics Teachers and Physics Education Research Conferences, the International Society for the Scholarship of Teaching and Learning, and the summer meetings of the American Association of Physics Teachers and Physics Education Research Conferences. Two manuscripts have been published: Dowd et al., in *Journal of Chemical Education,* and Dowd et al., in *Journal of Economics Education*.

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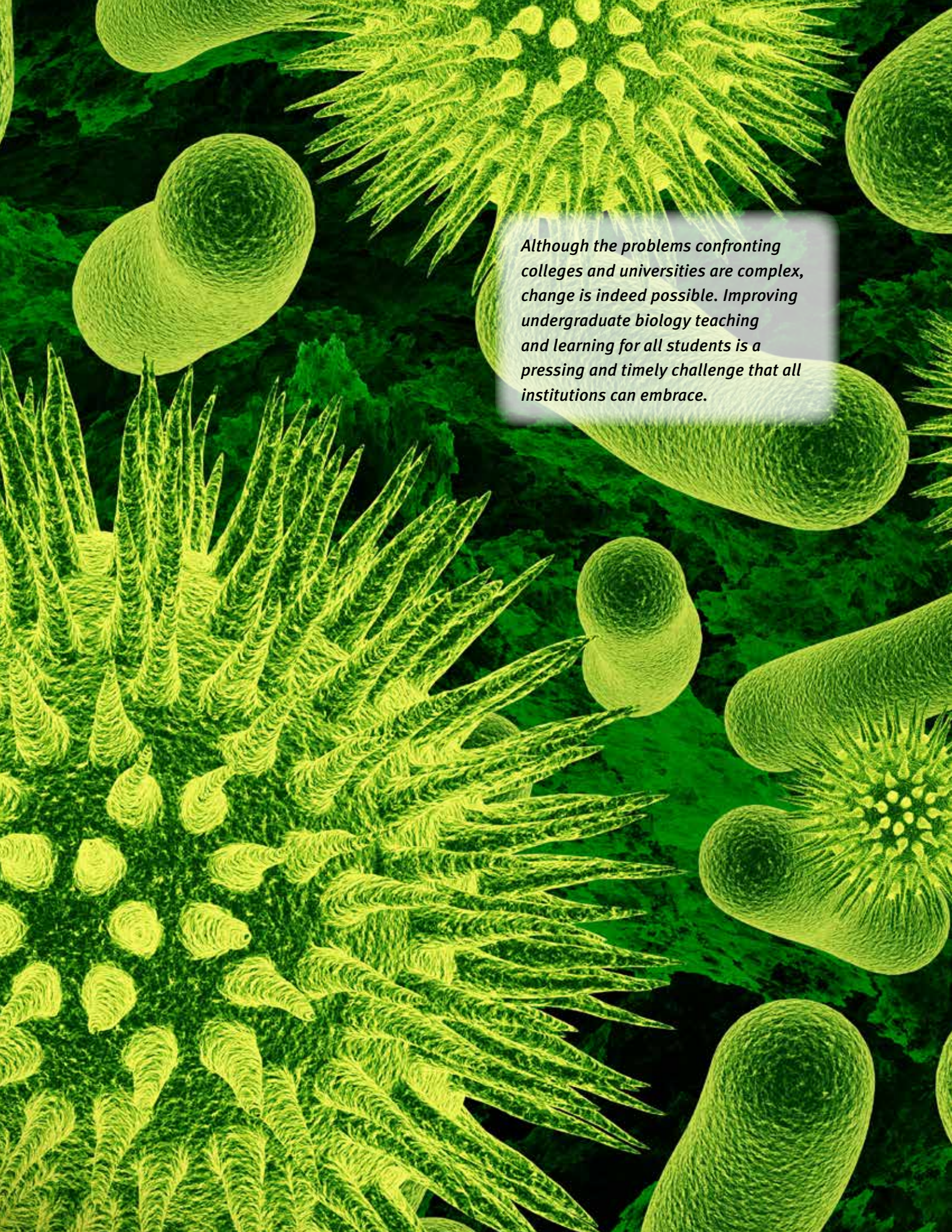

Although the problems confronting colleges and universities are complex, change is indeed possible. Improving undergraduate biology teaching and learning for all students is a pressing and timely challenge that all institutions can embrace.

APPENDIX A

PROJECTS IN THE FIELD

TABLE 8: 2013 Vision and Change Conference Abstracts

For more information about a specific project, contact the submitting author or visit www.visionandchange.org/project-locator/

Submitting Author	**Company or Institution**	**Project Title**	**Additional Contributors**	**Summary of Project Goal** (for complete project abstract, see www.visionandchange.org/project-locator/)
Susan Musante	American Institute of Biological Sciences	Building Leadership Capacity for Transformational Change	Teresa C. Balser, University of Florida; Charlene D'Avanzo, Hampshire College; Muriel Poston, Pitzer College	To determine how best to structure and implement a leadership program that will build the capacity of a life science department's leaders to implement and evaluate changes to better reflect the goals described in the Vision and Change report.
Amy Chang	American Society for Microbiology	Biology Scholars Program: Faculty Address Scholarly Teaching	Loretta Brancaccio-Taras, Kingsborough Community College, CUNY	To empower biologists to be leaders in science education and catalyze professional societies to sustain education reform.
Kelly Gull	American Society for Microbiology	ASM Conference for Undergraduate Educators Promotes Change	Amy L. Chang, American Society for Microbiology	To improve teaching and learning in undergraduate biology; identify concepts, understanding, and skills in biology; and develop a robust community of practice.
Marsha Lakes Matyas	American Physiological Society	Implementing Vision and Change Through Professional Society Programs	Melinda E. Lowy, Miranda Byse, C. Brooke Bruthers, Martin Frank	The American Physiological Society (APS) seeks to address the six major areas for professional society contributions to the Vision and Change effort by expanding existing programs and initiating new programs for students and faculty.
Sarah Goodwin	American Society for Cell Biology (ASCB) and University of California, San Francisco (UCSF)	Open Access Videos to Support Active Learning in Biology	Laurence Clement, UCSF and ASCB; Ron Vale, UCSF and HHMI	To support current efforts to implement and scale Vision and Change–aligned activities by providing the PULSE community with open-access educational resources.
Binaben Vanmali	Arizona State University	Biology Education Reform at Arizona State University	Miles Orchinik, Arizona State University	To educate students so that, upon graduation, they will be scientifically literate citizens and to encourage and assist faculty members in the transition to student-centered learning and meaningful assessments.
Jen Page	Association of American Medical Colleges	Pre–Health Collection: Help for Interdisciplinary Courses		To support innovation in undergraduate curricula, particularly biology curricula, by providing access to teaching materials to help revise and enhance existing curricula or develop new courses.
Linnea Fletcher	Austin Community College	Cross-Disciplinary Undergraduate Research	Patricia Phelps, George Staff, Sulatha Dwarakanath, Austin Community College	To make science and math courses more student centered and hands on, offer cross-disciplinary undergraduate research opportunities, develop long-term research projects shared across disciplines to integrate curricula for students, and embed these measures within the assessment and evaluation cycle at the college.
JoDale Ales	Baton Rouge Community College	Vision and Change in a Community College Biology Sequence		To encourage biology faculty to participate in Vision and Change and PULSE activities, redesign a general biology sequence for nonmajors that is focused on core concepts relevant to today's students, and implement and assess the new courses.
Gita Bangera	Bellevue College	Classroom Research Experience for Community College Students	K. Harrington, Tacoma Community College; A. Gargas, Symbiology LLC; R. Jeffers, C. Vermilyea, Bellevue College; L. Thomashow, D. Weller, U.S. Department of Agriculture, Agricultural Research Service	To take the field-tested ComGen approach of using authentic research as pedagogy to community colleges in the Pacific Northwest.

Submitting Author	**Company or Institution**	**Project Title**	**Additional Contributors**	**Summary of Project Goal** (for complete project abstract, see www.visionandchange.org/project-locator/)
Allison Wilson	Benedictine University	Improving the Introductory Biology Experience	Robin Rylaarsdam, Benedictine University	To improve the continuity and comprehension of biology materials and to promote higher order thinking at an early stage of the curriculum.
Clare O'Connor	Boston College	Introductory Lab Involves Students in Genomics Research	Laura E. Hake, Douglas M. Warner, Boston College	To increase core student competencies associated with the application of the scientific process, the use of quantitative reasoning, and the communication of scientific results and ideas.
Melissa Kosinski-Collins	Brandeis University	Huntington's as an Interdisciplinary Lab for Intro Biology	Jason Pontrello, Brandeis University	To emphasize the cohesive nature of chemistry and biology while focusing on a few core biological concepts.
Carol Maillet	Brescia University	Weaving a Conceptual Thread: A Cross-Curricular Approach	Conrad S. Toepfer, Brescia University	To provide students with a multifaceted exposure to complex biological systems, practice in evaluating and synthesizing information from multiple sources, opportunities to collaborate on intradisciplinary teams, and exposure to quantitative analysis and practice with large data sets.
Anne Marie Bergen	California Polytechnic State University	Bio 211: Building a Studio, Active-Learning Biology Course		To create a studio-based biology course for future elementary teachers that is framed around the core concepts and scientific practices highlighted in Vision and Change and the K–12 National Science Framework.
Susan Baxter	California State University (CSU)	CSUPERB: A System-Wide Biotech Community Promoting Change	James Henderson, CSU, Los Angeles	To promote a commitment to change and engage the biology community in the implementation of change.
Ulrike Muller	California State University (CSU)	Issue Driven Learning (IDL) in a Non-Major Biology Course	Susan Elrod, CSU, Fresno	To improve student performance in a high-enrollment, high-failure general education course for nonbiology majors without increasing faculty workload while still maintaining course content and rigor.
Elizabeth Torres	California State University, Los Angeles (CSULA)	Improving Quantitative Skills of CSULA Life Science Majors	Silvia Heubach, CSULA	To improve the quantitative skills of biology and microbiology majors by modifying mathematics, introductory biology, and physics courses, by establishing a Center for Interdisciplinary Quantitative Analysis (CINQA), and by developing a new bioinformatics minor.
Denise Garcia	California State University (CSU), San Marcos	Quantitative and Computational Skill in Biology Curriculum	Charles De Leone, Marie Thomas, Keith Trujillo, Victor Rocha, Richard Bray, CSU, San Marcos	To implement a modern, interdisciplinary quantitative and computational curriculum that prepares undergraduate science majors for the challenges and careers of the 21st century.
David Koetje	Calvin College	Aligning Introductory Biology Curricula to Vision and Change	Amy Wilstermann, Herbert Fynewever, Calvin College	To introduce students to biological core concepts, begin the process of core competency development, and provide opportunities to integrate concepts from biology and other STEM disciplines.
Christopher Cullis	Case Western Reserve University	Undergraduates Developing Resources for Lost Crops of Africa		To engage students in a course that can provide research resources for faculty and graduate students in the developing world.
Joseph Koonce	Case Western Reserve University	Biology Curriculum Change Through Use of Civic Engagement		To improve student-learning gains through the development and implementation of undergraduate environmental-service learning and community-based research curricula and courses; to provide venues for public environmental education by undergraduates, as well as enhance access to environmental careers for undergraduates; and to meet needs of the region's nonprofit and government-sponsored environmental organizations addressing natural resource conservation and development issues.
Juville Dario-Becker	Central Virginia Community College	Vision and Change: A Framework for Introductory Biology Re-Design	Jessica Hogan, Central Virginia Community College	To reengineer and redesign high-enrollment, high-attrition courses, including a two-semester biology sequence taught in all 23 community colleges in Virginia, with the primary goal of improving student success.

Submitting Author	**Company or Institution**	**Project Title**	**Additional Contributors**	**Summary of Project Goal** (for complete project abstract, see www.visionandchange.org/project-locator/)
Ian Quitadamo	Central Washington University	Community-Based Inquiry Improves Critical Thinking in STEM		To use community-based inquiry to measurably improve student critical-thinking outcomes and to build faculty expertise and capacity to teach critical thinking in STEM courses.
Joyce Hardy	Chadron State College	Stratifying Concepts/ Competencies in the Biology Program	Ann Buchmann, Wendy Jamison, Mathew Brust, Chadron State College	To develop a coherent, structured curriculum that includes significant core concepts, systems-level integration with microlevel processes, the multidisciplinary application of knowledge, and professional skills and attitudes.
Elaine Johnson	City College of San Francisco	Bio-Link Aligns With Vision and Change Recommendations		To increase the number and diversity of well-trained technicians in the workforce; meet the growing needs of industry for appropriately trained technicians; and institutionalize community college educational practices that make high-quality education and training in the concepts, tool, skills, processes, regulatory structure, and ethics of biotechnology available to all students.
Sally Hoskins	City College of the City University of New York	Primary Literature for First-Year Students: Adapting C.R.E.A.T.E	Kristy Kenyon, Hobart and William Smith Colleges	To adapt the C.R.E.A.T.E. (Consider, Read, Elucidate hypotheses, Analyze and interpret the data, and Think of the next Experiment) strategy for first-year students; teach a new course, "C.R.E.A.T.E. Cornerstone: Introduction to Scientific Thinking," for entering first-year students; and assess potential cognitive and affective gains made by students during the semester-long course.
David Hansen	Claremont McKenna, Pitzer, and Scripps Colleges	The Development of Integrated Introductory Science Courses	Bryan Thines, Claremont McKenna, Pitzer, and Scripps Colleges	To create and teach introductory interdisciplinary science courses that focus on quantitative competency and use facts judiciously as a means of illustrating concepts rather than as items to be memorized in isolation.
Emily Wiley	Claremont McKenna, Pitzer, and Scripps Colleges	Ciliate Genomics Consortium: Teaching–Research Integration		To improve the feasibility or sustainability of undergraduate research in the classroom through melding faculty research goals with student research efforts in a professional learning community model, increase early student participation in authentic research by integrating opportunities into a variety of commonly taught biology courses at different levels and types of institutions, enrich classroom undergraduate research experiences through the immediate Web publication of students' original findings to an appropriate user group, and expand science leadership opportunities for students.
Tamara McNealy	Clemson University	Microbiology Major Curriculum Innovations		To streamline the currently offered nine microbiology labs into a three-semester laboratory series; integrate core competencies across microbiology, using reinforcement without redundancy; focus on hands-on, student-centered learning in small class sizes and active-learning components; promote a commitment to change in which faculty, staff, and graduate and undergraduate students are involved in the change process; and engage faculty campuswide through the dissemination of these methods and innovative strategies.
David Micklos	Cold Spring Harbor Laboratory	DNA Barcoding: Scalable Infrastructure for Student Research	Bruce Nash, Jermel Watkins, Cornel Ghiban, Mohammed Khalfan, Sheldon McKay, Eunsook Jeong, Susan Lauter, Christine Marizzi, Melissa Lee, Antonia Florio, Cold Spring Harbor Laboratory; Oscar Pineda-Catalan, American Museum of Natural History	To use DNA bar coding to bring open-ended experimentation into lower level undergraduate courses, providing a practical means to engage large numbers of students in meaningful research.

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Kenneth Belanger	Colgate University	Peer-Led Team Learning in a Cell/Molecular Biology Course		To provide beginning biology students with the skills to engage in solving complex problems, to help them integrate material learned in the school's introductory cell/molecular biology course into subsequent courses, to help them see the advantages of collaborative learning, and to provide leadership opportunities for talented, invested advanced students that help them become better learners and teachers.
Meena Balgopal	Colorado State University	Writing-to-Learn to Increase Scientific Literacy Skills	Alison M. Wallace, Ellen Brisch, Minnesota State University Moorhead; Steven Dahlberg, White Earth Tribal College; Paul Laybourn, Colorado State University	To promote learning through the integration of writing-to-learn strategies in undergraduate biology courses for majors and nonmajors and to help learners make sense of scientific concepts, find relevancy in real-world examples, and develop evidence-based scientific claims after reading scientific articles on socioscientific issues written for the general public.
Gillian Bowser	Colorado State University	Rocky Mountain Science and Sustainability Network Academy	Mark Brown, Colorado State University; Elizabeth Davis, University of New Haven	To improve STEM learning for all students by engaging minority students in the science behind sustainability and the conservation of public lands and to create global leaders in sustainability through cohort-based learning.
Chris Paradise	Davidson College	Implementing Vision and Change in Introductory Biology Using a New Text	A. Malcolm Campbell, Laurie J. Heyer, Mark J. Barsoum, Patrick J. Sellers, Davidson College	To improve introductory biology education by writing a textbook that uses the core recommendations of Vision and Change as its foundation.
John Hatherill	Del Mar College	Implementing Vision and Change with the HHMI National Genomics Initiative	Daiyuan Zhang, Del Mar College	To develop a new Vision and Change concept-based curriculum by using actual research and case studies and to prepare students for the high-performance workplace by equipping them with critical or independent thinking and problem-solving abilities and transforming them by igniting and captivating them with the thrill of real scientific discoveries.
Andrew Lloyd	Delaware State University	Interventions Targeting Student Success in Freshman Biology	Rashida Z. Davis, Cynthia van Golen, Delaware State University	To improve success rates in first-year biology survey courses by adopting the Vision and Change student-learning objectives and modifying courses so that their objectives integrate smoothly with the Vision and Change objectives.
Julie Basu Ray	Dillard University (DU)	'SI-QEP—LAMP' Tripod strategy- DU's blueprint to the future.		To ensure the success of all students by enhancing their communication skills by grounding them in critical thinking.
Brad Elder	Doane College	A 15 Year Curriculum Wide Program Change	Barb Clement, Tessa Durham Brooks, Erin Doyle, Ramesh Laungani, Kate Marley, Doane College	To develop student abilities in experimental design, execution, analysis, and communication across biological fields through the introduction of an intensive three-semester independent research capstone experience.
Kate Marley	Doane College	Curriculum Alignment with Vision and Change Concepts and Competencies		To develop life science graduates who will have a strong conceptual understanding of biology, as well as critical-thinking, scientific-thinking, communication, collaboration, and quantitative-reasoning skills, by means of a strong emphasis on authentic research.
Shivanthi Anandan	Drexel University	Faculty Learning Communities for Mentoring Biology Faculty	Barbara Hornum, Drexel University	To promote faculty learning communities as vital components of the academy and as instruments for advancing a better understanding of biology teaching and learning.
Jennifer Stanford	Drexel University	Research Experiences and Career Mentoring for Large Cohorts	Laura E. Duwel, Drexel University; Elizabeth A. Spudich, Thomas Jefferson University	To help students learn to critically read and analyze their own work and the biology literature, communicate effectively, conduct science ethically, engage in the scientific process, and be prepared for a career or future schooling.
Nancy Trun	Duquesne University	Using Novel Research on Community-Based Problems in Labs		To develop and test Application-Based Service Learning to improve the quality of STEM courses at a number of different types of educational institutions.

Submitting Author	**Company or Institution**	**Project Title**	**Additional Contributors**	**Summary of Project Goal** (for complete project abstract, see www.visionandchange.org/project-locator/)
Amy Mulnix	Earlham College	Aligning the Earlham Biology Major with Vision and Change Recommendations	Jose I. Pareja, Earlham College	To make teaching and assessment of competencies as outlined in part in Vision and Change—quantitative reasoning; information literacy; the ability to evaluate, apply, and synthesize scientific information; and oral and written communication—more robust in required courses for majors.
Teresa Mourad	Ecological Society of America	Building Communities, Leveraging Partnerships		To develop educational materials on data literacy and to build and support communities of practice in order to promote active-learning pedagogies.
Rachelle Spell	Emory University	Redefining Authentic Research in Introductory Biology	Christopher Beck, Emory University	To define the essential components of authentic research in introductory biology courses, identify the barriers to implementing authentic research experiences, and evaluate current practices in introductory biology in relation to authentic research experiences.
Pamela Pape-Lindstrom	Everett Community College	Systems Biology and Computer Modeling Across the Curriculum		To add a systems perspective to biological content; provide computer modeling and simulation classroom experiences to help students understand that biological systems are interactive, dynamic, and complex; and enhance the curriculum by providing similar opportunities for nonscience majors.
James Hewlett	Finger Lakes Community College	Community College Undergraduate Research Initiative	John VanNiel, Finger Lakes Community College; Jackie Crisman, Jamestown Community College; Virginia Balke, Delaware Technical Community College; James Jacob, Tompkins Cortland Community College	To promote a deeper conceptual understanding in introductory science classes while at the same time exposing students to ongoing research projects.
Ramon Gomez	Florida International University	Innovations in Statistics Courses for Biology Students		To improve the quality of undergraduate education as well as increase students' likelihood of excelling in biological sciences–related careers.
Sunshine Brosi	Frostburg State University	Ethnobiology Educational Network: A societal perspective	Patricia Harrison, Will McClatchey, Botanical Research Institute of Texas	To develop and promote ethnobiology education and in turn enhance STEM education through the lens of ethnobiology.
James McNeil	George Mason University	Smithsonian–Mason Semester teaches conservation in practice	Jennifer Buff, Anneke DeLuycker, Stephanie Lessard-Pilon, A. Alonso Aguirre, Smithsonian–Mason School of Conservation	To involve conservation practitioners and nontraditional partners representing disciplines related to conservation but not often included in undergraduate courses on the subject (e.g., economics, conflict resolution, communication, policy, management, public education, ethics), engage students in real-world case studies and projects that illustrate the multifaceted and transdisciplinary nature of conservation studies, and provide the students with opportunities to practice their skills in a meaningful way.
Hartmut Doebel	George Washington University	Lecture Less in Large Enrollment Classes		To create a learner-centered classroom, develop critical-thinking skills, foster teamwork, and make learning exciting.
Judy Awong-Taylor	Georgia Gwinnett College	An Interdisciplinary Approach to Implementing Change	Thomas Mundie, Clay Runck, Allison D'Costa, Greta Giles, David Pursell, Georgia Gwinnett College	To enhance student engagement and learning in STEM disciplines and to support faculty innovation and leadership.
Jung Choi	Georgia Institute of Technology	Student-Centered Learning in Biology at Georgia Tech	Shana Kerr, Georgia Institute of Technology	To promote student learning of skills and processes, especially quantitative analysis and reasoning.
Erin Morrey	Georgia Perimeter College	Comparing Traditional and Module-Based Intro Biology Class		To increase retention and success rates in an introductory course for biology majors through the introduction of active teaching of central themes while covering the material required by the common course outline.

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Laura Regassa	Georgia Southern University	Providing Context via Guided Inquiry and Service Learning	Stephen P. Vives, Georgia Southern University	To enhance student learning, with particular emphasis on higher order learning skills, by generating a student-centered classroom that conveys key concepts and problem-solving skills within relevant contexts.
Paul Ulrich	Georgia State University	Developing Scalable Research Experiences for Undergraduates	Dabney Dixon, Georgia State University	To help students establish critical-thinking and technical skills in biology.
Nancy Staub	Gonzaga University	Biology Curriculum Redesign Based on Vision and Change	Brook O. Swanson, Marianne Poxleitner, Kirk Anders, Gonzaga University	To increase retention, engagement, comprehension, critical-thinking skills, and a sense of community among students.
Brad Goodner	Hiram College	Science-based Entrepreneurship in Introductory Biology	Sandy Madar, Jenn Clark, Hiram College	To better prepare students to understand the work of biologists.
Kristy Kenyon	Hobart and William Smith Colleges	A National Perspective of CREATE in Scientific Curricula	Sally G. Hoskins, City College of the City University of New York	To transform undergraduate science education by shifting the center of the classroom universe from the textbook to the journal article.
Jeffrey Hill	Idaho State University	Impacts of Mentored Research Experiences in Freshman Biology	Carolyn F. Weber, Koreen A. Boydstun, Taylor T. Goodnoe, Shannon Lynch, Idaho State University	To encourage faculty members to engage students in their own research while they accrue workload credit for undergraduate teaching.
Whitney Schlegel	Indiana University Bloomington	Bay View Alliance: Building Cultures of Teaching Improvement	Mary Huber, Pat Hutchings, Bay View Alliance; Linda Slakey, Association of American Colleges & Universities; Whitney Schlegel, Indiana University Bloomington; Lorne Whitehead, University of British Columbia	To accelerate the adaptation, exploration, and effective integration of methods of instruction that support improved student learning.
Kathleen Marrs	Indiana University–Purdue University Indianapolis (IUPUI)	IUPUI Undergraduate STEM Laboratory Transformation	Simon Atkinson, IUPUI	To create a better blend of scientific teaching and classroom research to make teaching more evidence based and classrooms more student centered.
Jo Anne Powell-Coffman	Iowa State University	A Model for Emergent Change at Iowa State University	Craig Ogilvie, Clark Coffman, Emily Elliott, Diane Bassham, Iowa State University	To increase student engagement and learning in first- and second-year science courses.
Raphael Isokpehi	Jackson State University	Visual Analytics in Biology Curriculum Network	Shaneka S. Simmons, Jackson State University; Jian Chen, University of Maryland, Baltimore County; Edu Suarez-Martinez, University of Puerto Rico at Ponce; Robert Dottin, Hunter College of the City University of New York	To contribute to national efforts to change the way the core concepts for biology literacy and practice are taught and learned, and to facilitate and promote the collaboration of researchers, educators, and students who are developing approaches for incorporating visual analytics into biology undergraduate education.
Joanna Mott	James Madison University	Building Momentum for Change in a Biology Department		To build momentum, using a stepwise strategy, for faculty engagement and leadership for curriculum change in the biology major.
Louise Temple	James Madison University	Group Research: Experiment in Efficiency of Delivery		To offer original research opportunities to more undergraduates by developing experimental questions that can be addressed by small groups of students mentored by one faculty member.
Joel Schildbach	Johns Hopkins University	Integrating Research into the Freshman Experience	Forrest Spencer, Johns Hopkins University School of Medicine	To expand research options for first-year undergraduates and to engage them in worthy activities both in the classroom and in the lab.

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Richard Shingles	Johns Hopkins University	Active, Group, and Authentic Learning in Large Introductory	Richard E. McCarty, Rebecca Pearlman, Christov Roberson, Johns Hopkins University	To increase attendance in general biology, make class time worthwhile to students, develop a learner-centered environment in the classroom, and apply concepts learned in the classroom to the real world.
Loretta Brancaccio-Taras	Kingsborough Community College	Departmental Assessment to Examine Student Learning	Mary T. Ortiz, Kristin Polizzotto, Kingsborough Community College	To develop a standardized departmental assessment plan using backward design to determine whether students are meeting the stated learning outcomes of the introductory biology course sequence.
Gail Rowe	La Roche College	BioSOLVE Brings Undergrad Research to a Small College		To bring a real lab research experience, including its application to social issues, to a nonresearch undergraduate biology program.
Stacey Kiser	Lane Community College	National Association of Biology Teachers/ Society for College Science Teachers Vision and Change Implementers Network	Jaclyn Reeves-Pepin, Donald P. French, National Association of Biology Teachers; Brian Shmaefsky, Society for College Science Teachers	To leverage the membership and activities of professional associations to create a national network of faculty dedicated to promoting Vision and Change transformations.
Gary Reiness	Lewis and Clark College	Ambassadors for Curricular Change		To support and promote the changes in life science education recommended by the Vision and Change report.
Anne Kruchten	Linfield College	Interdisciplinary Science Workshop for Incoming Students		To help biology students tap into the interdisciplinary nature of science and to enhance their ability to communicate and collaborate with those in other disciplines.
Catherine Reinke	Linfield College	Fostering Student-Centered Inter-Investigator Collaborations		To demystify the practice of science for undergraduate students by facilitating their authentic contributions to the scientific community.
William Wischusen	Louisiana State University	Student Engagement in a Flipped Course		To determine the impact on student performance of different student activities commonly used in flipped classes.
Thomas Eddinger	Marquette University	Writing and Exam Corrections Improve Student Learning	Anita L. Manogaran, Michelle Mynelie, Martin St. Maurice, Marquette University	To assess how certain interventions, such as peer-reviewed writing assignments and exam corrections, improve student learning.
Graham Walker	Massachusetts Institute of Technology	Innovations in Using Digital Approaches to Teach biology		To engage the passion of faculty and students, both on campus and around the world, by exploiting the potential of digital approaches to improve learning through innovative uses of technology and technology-enabled pedagogies.
Diane Ebert-May	Michigan State University	Creating a Coherent Gateway for STEM Teaching and Learning	Tammy Long, Robert T. Pennock, Mark Voit, Michigan State University	To reform gateway courses and change the culture of research universities to emphasize the importance of teaching and learning.
Robert T. Pennock	Michigan State University	Learning with Digital Evolution Software	Amy Lark, Wendy Johnson, Louise Mead, Jim Smith, Gail Richmond, Michigan State University	To develop software and curricula to allow students to learn about evolution and the nature of science by using specially developed versions of the same digital evolution model systems that are used for basic research in experimental evolution.
Nancy Auer	Michigan Technological University	General Biology as Discovering the Story of Life		To help students grasp and discover the story of life, see how it grows and unfolds as they move though their biology class and into other classes, understand and speak about concepts to others, develop synthesis and critical evaluation skills, and evaluate how they are doing (i.e., know their own grade).

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Grant Gardner	Middle Tennessee State University	Preparing Faculty to Engage in Vision and Change		To promote faculty teaching professional development that aligns with various Vision and Change action items by providing information about the state of biology education research and relevant findings, translating education research results into practical solutions for classroom instruction, and establishing sustained support and collaborative networks to implement research-based instructional strategies in the classroom.
Ann Batiza	Milwaukee School of Engineering	New Tools for Learning about Biological Energy Transfer		To increase student understanding of what powers life.
Lawrence Blumer	Morehouse College	Learning Gains from Guided-Inquiry Labs with Bean Beetles	Christopher W. Beck, Emory University	To increase the use of guided inquiry in undergraduate laboratory courses and to foster the development of new guided-inquiry experiments with the bean beetle *(Callosobruchus maculatus).*
Lawrence Blumer	Morehouse College	Association for Biology Laboratory Education: A Vision and Change Resource		To improve the undergraduate biology laboratory experience by promoting the development and dissemination of interesting, innovative, and reliable laboratory exercises.
Christine Hohmann	Morgan State University	Learning Science by Writing: Interdisciplinary Approaches	Ernest Steele, Stella Hargett, Morgan State University; Julie Reynolds, Jason Dowd, Duke University	To engage students as active participants in the generation of research literature–based knowledge and to enhance literacy in biomedical and bioenvironmental concepts across STEM and social/behavioral sciences disciplines.
Sarah Corey-Rivas	New Mexico Highlands University	Student-Centered Introductory Biology and Forestry at a HSI	Mary Shaw, Sara Brown, New Mexico Highlands University	To increase learning, retention, and graduation rates at an open-enrollment, rural Hispanic-serving Institution through the development and support of a student-centered learning environment.
Rebecca Reiss	New Mexico Institute of Mining and Technology	Preparing the Next Generation of Bioengineers		To increase understanding on the part of both students and faculty of the rapidly changing interface between biology and engineering and to prepare students for upper-division biology courses that include increased exposure to research projects.
William Boecklen	New Mexico State University	Integrating Biology and Math Education at New Mexico State	Mary Ballyk, Avis James, New Mexico State University	To fully integrate undergraduate biology and mathematics education at a large state institution that serves an ethnically diverse and economically diverse student body.
A.E. Dreyfuss	New York City College of Technology, CUNY	PLTL and PLTLIS		To engage students by having them work together on problems and course material under the guidance of a trained student peer leader and to support practitioners (faculty, administrators, learning specialists, peer leaders) in order to foster active student learning through peer-led teams.
Ignatius Tan	New York University	Biology Curriculum Changes at New York University.	Mark L. Siegal, New York University	To integrate core concepts and competencies throughout the biology curriculum, focus on student-centered learning, and promote a campuswide commitment to change.
Robert Newman	North Carolina Agricultural and Technical (A & T) State University	Experiential Research-Based Biology Curriculum	Mary A. Smith, Gregory Goins, Scott Harrison, Catherine White, North Carolina A & T State University	To adopt instructional strategies and a biology curriculum that will enhance student success, graduation rates, and retention in the biological sciences.
Miriam Ferzli	North Carolina (NC) State University	How Practicing Authentic Research Benefits Underclassmen	Mary Beth Hawkins, Elizabeth Overman, NC State University; Johnavae Campbell, University of North Carolina at Chapel Hill	To provide students with opportunities to engage in authentic research practice through a research track embedded in current curricula.
Emina Stojkovic	Northeastern Illinois University	Research Projects in Biochemistry and Molecular Biology		To develop confident and collaborative scientists who will be comfortable with the conduct of authentic research, including analyzing data and discussing conclusions and future directions.

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Gail Begley	Northeastern University	Vision and Change–ing the Biology Major		To move the undergraduate biology experience to a more competency-based and inquiry-rich program that emphasizes interdisciplinary connections and the important applications of mathematics in biology.
Sharon Gusky	Northwestern Connecticut Community College	Engaging Faculty in a Peer Review of Outcomes and Assessment		To ensure that all biology courses have clearly defined and measurable outcomes, that these outcomes are included in the course syllabi, and that assessments are clearly aligned with outcomes.
Stanley Lo	Northwestern University	How a Scientific Society Promotes and Supports Change	Su L. Swarat, Gregory J. Light, Denise L. Drane, Northwestern University	To design and implement a faculty development program that is meaningful to participants' teaching contexts and that changes conceptions of teaching in addition to approaches to teaching.
Taylor Allen	Oberlin College	Transformation of Biology Courses and Department at Oberlin	Marta Laskowski, Liliana Milkova, Maureen Peters, Oberlin College	To boost the extent to which the learning environment in both the classroom and the laboratory is centered on the student and high-end cognition.
Caroline Breitenberger	Ohio State University	Designing a Student-Centered Integrated Biology Major Course	Stephen W. Chordas III, Judith S. Ridgway, Ohio State University	To develop an integrated biology course to serve as the core course in the biology major.
Judy Ridgway	Ohio State University	Ongoing, Developmentally Appropriate TA (future faculty) PD	Isaac Ligocki, Jonathan Horn, Ohio State University	To develop a professional development system that prepares teaching assistants (TAs) to use the innovative pedagogies employed in our courses to support undergraduate student learning, prepares TAs to be future faculty, addresses the diversity of experience and interests within the TA population, and provides incentives for TAs to engage in professional development activities.
Sarah Wyatt	Ohio University	How a Scientific Society Promotes and Supports Change	Katie Engen, American Society of Plant Biologists (ASPB); Erin Dolan, University of Georgia	To determine how to put the recommendations of Vision and Change into practice and to guide the development of activities and resources that ASPB can offer its members as they put Vision and Change recommendations into practice with diverse students in a wide range of institutional contexts; to generate a set of core concepts, consistent with Vision and Change, that undergraduate biology majors should learn about plants; and to support selected individuals in participating in evidence-based professional development to adapt or develop educational materials.
Laurie Anderson	Ohio Wesleyan University	Teaching Continental-Scale Ecology with EREN		To create a model for collaborative ecological research that generates high-quality, publishable data involving undergraduate students and faculty across a continental-scale network of research sites.
Lori Kayes	Oregon State University	Making Small Changes to Big Courses	Krissi Hewitt, Robert Mason, Oregon State University	To redevelop the Principles of Biology series for majors so that it will be more aligned with Vision and Change, thereby increasing student learning, engagement, and long-term retention of materials.
Nitya Jacob	Oxford College of Emory University	Investigative Learning in an Introductory Biology Curriculum		To identify common learning outcomes in concepts and competencies for the first two courses for biology majors, map out a collective vision for the types of student learning experiences to be achieved in the two courses, and develop and implement practices in both courses to emphasize and support active learning, problem solving, collaborative discussion, collaborative inquiry and data analysis, exposure to authentic research, information literacy, and scientific communication.

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Marcy Kelly	Pace University	Assessing a Year-Long, Research Lab in a Core Biology Course	David S. Zuzga, LaSalle University	To adapt a yearlong laboratory program that develops a strong foundation in structure and function at the cellular and molecular level, in information flow, in exchange and storage through genes and proteins, and in pathways and transformations of energy and matter that are involved in cellular communication and responses to the environment.
Sarah Ades	Penn State	Integrating Research into the Undergraduate Curriculum		To develop a two-course progression that couples classroom learning with primary research, that integrates first-year students into the research community, and that provides a strong foundation in scientific inquiry and the skills for students to become lifelong educated consumers of science.
Richard Cyr	Penn State	Vision and Change in a Reformed Biology Curriculum	Denise Woodward, Pennsylvania State University	To fully integrate all core concepts and competencies into the first- and second-year biology curriculum, with spillover into the junior and senior (as well as graduate) levels, to retain students in their first two years, and to develop a solid student understanding of how science is done and how this knowledge can help solve problems confronting society.
April Maskiewicz	Point Loma Nazarene University	Promoting Scientific Reasoning about Matter and Energy		To promote undergraduate student thinking and reasoning about matter and energy transformations and pathways—one of the five core biological concepts identified in Vision and Change—and to identify curricular activities that help undergraduates develop scientific ways of reasoning about matter and energy in biological systems.
Edward Bartlett	Purdue University	Integrating Statistics into the Life Sciences Curriculum	James Forney, Ann Rundell, Kari Clase, Stephanie Gardner, Omolola Adedokun, Dennis Minchella, Purdue University–West Lafayette	To bring together faculty and undergraduate students from an array of academic institutions and disciplines to provide a facilitated hands-on experience focusing on experiment design and statistical analysis within the context of life science–related research projects.
Kari Clase	Purdue University	Multidisciplinary Effort to Address Education in New Biology	Kristy Halverson, University of Southern Mississippi; Robin Heyden, Ty Heyden, Jenna Rickus, Bindley Bioscience Center	To develop a biotechnology minor with the Colleges of Agriculture, Pharmacy, and Science and Technology that reflects today's changing biology; draws students from science, technology, and engineering majors across campus; and includes new approaches to the assessment and measurement of student-learning outcomes.
Stephanie Gardner	Purdue University	Research-Based Introductory Biology Laboratory Courses	Dennis J. Minchella, Purdue University	To introduce first-year biology majors to the culture of scientific discovery by engaging them in authentic research projects as part of their introductory biology curriculum and to increase student retention in science by fueling their interest in critical thinking and inquiry.
Nancy Pelaez	Purdue University	Informed Learning Practices in Biology Using Peer Leaders	Clarence D Maybee, Maribeth Slebodnik, Purdue University	To introduce undergraduates to the practices that inform biology professionals and explicitly address the potential for students to inform themselves in a biology course for first-year undergraduate students.
George Plopper	Rensselaer Polytechnic Institute	Cascading Curriculum Changes from Course to Institute-Level	Susan Gilbert, Rensselaer Polytechnic Institute	To implement Vision and Change core concepts and competencies as outcomes for all (~450) undergraduate biology students, map all 49 undergraduate courses and five core curriculum courses to align with these concepts and competencies, use core concepts and competencies to assess the efficacy of the biology undergraduate programs, promote faculty development that includes backward course design techniques, and introduce new teaching methods into an upper-division undergraduate/graduate course.
Beth Beason-Abmayr	Rice University	Toward Student-Centered Active Learning at Rice (SCAL@R)	David Caprette, Elizabeth Eich, Scott Solomon, Rice University	To create a student-centered learning experience that gives biology students an intellectual framework and adaptable skill set, leading them to incorporate new knowledge as they advance in their studies and as information and technologies change.

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Gregg Transue	Rutgers University–Piscataway/New Brunswick	Transforming Rutgers: Large (*n* >2100) General Biology Course		To integrate the Vision and Change core concepts and competencies throughout the curriculum and provide student-centered learning opportunities.
Elizabeth Dinsdale	San Diego State University	Microbes, Metagenomes and Marine Mammals: Enabling the Next Generation of Researchers	Robert A. Edwards, Meredith Houle Vaughn, San Diego State University	To inspire student learning by allowing students to use the latest technology and generate new data, engage students by integrating teaching and research, and enable students to integrate genomics in areas of biology and ecology.
Anca Segall	San Diego State University (SDSU)	Biomath at SDSU: Leveraging Undergraduate Research	Peter Salamon, San Diego State University	To increase the number of undergraduates trained in an interdisciplinary fashion and who pursue studies in mathematical biology.
Kathy Williams	San Diego State University	Assessing Scientific Literacy in General Education Courses	Stephen Schellenberg, Catherine Atkins, San Diego State University	To improve biology learning by examining which competencies students are gaining in biology and related courses and to develop cost-efficient strategies that continue to generate student success in all science courses.
Vinay Chaudhri	SRI International	Inquire: An Intelligent Textbook for Biology	Jeremy Roschelle, Aaron Spaulding, Britte Cheng, Louise Yarnall, SRI International; Craig Heller, Stanford University	To integrate Vision and Change core concepts and competencies throughout the curriculum; focus on student-centered learning by engaging students as active participants and ensuring that undergraduate biology courses are active, outcome oriented, inquiry driven, and relevant; and engage the biology community in the implementation of change by promoting more concept-oriented biology courses, by helping all students learn how to integrate facts into larger conceptual contexts, and by creating active-learning environments for all students, even those in first-year biology courses.
Xiao-Ning Zhang	St. Bonaventure University	Connect Classroom Learning with Real World Applications	Paula Kenneson, Saint Bonaventure University	To test the feasibility of using real research projects in teaching labs; bridge the gap between knowledge transmitted by lecture in the classroom and applications of that knowledge; train undergraduate students to become scientific learners and critical thinkers; and train undergraduate students to talk to the general public about biology research.
Carrie Dollar	St. Clair County Community College	Effective Instruction and Authentic Research in Biology	Carrie Dollar, St. Clair County Community College	To initiate improvements in undergraduate biology education through the introduction of an authentic research experience into an introductory biology course and the integration of research-based, effective instructional practices into undergraduate biology courses.
Samantha Elliott	St. Mary's College of Maryland	Once Weekly Structured Group Work Narrows Achievement Gap	Holly L. Gorton, Lin Y. Muilenburg, St. Mary's College of Maryland	To increase overall student success in the introductory biology course for first-semester biology majors and to retain underrepresented minorities in the discipline by including some best practices as outlined in the Vision and Change report.
Martha Cyert	Stanford University	A Large Lab Course That Delivers Genuine Research Experience	T. Stearns, D. Hekmat-Scafe, P. Seawell, S. Brownell, M. Kloser, University of Notre Dame	To increase students' critical-thinking skills and confidence and interest in research-related tasks.
Tadashi Fukami	Stanford University	Teaching–Research Integration in an Ecological Curriculum	Sara E. Brownell, University of Washington; Matthew J. Kloser, University of Notre Dame; Patricia C. Seawell, Nona R. Chiariello, Richard J. Shavelson, Stanford University	To provide students with an opportunity to work in an introductory, ecology-based lab course with many of the hallmarks of authentic research, including a single longitudinal question that is the focus for the whole quarter, research questions with unknown answers, the use of modern ecological and molecular techniques in the field and in the laboratory, an emphasis on data analysis, and collaboration among lab peers.

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John Moore	Taylor University	Learning to Learn	Jeffrey Regier, Taylor University	To provide students with a learning environment that truly mimics the reality of the nature of science in biology.
Jacqueline Tanaka	Temple University	Early Intervention: Increasing 'at Risk' Student Success		To better prepare at-risk students to succeed in the biology curriculum through an early intervention–type course, Biological Reasoning, that focuses on effective learning strategies adopted from Vision and Change leaders.
Elizabeth Spudich	Thomas Jefferson University	Rethinking Undergraduate Anatomy Education	Jennifer S. Stanford, Drexel University; Victoria M. Egerton, University of Manchester (UK)	To introduce students in anatomy and physiology courses to more content and an increased pace of presentation of that content, the three-dimensional nature of regional anatomy, and student-driven design and pacing of learning through a course design that integrates other aspects of the curriculum, uses real-world applications to help foster student curiosity, and focuses on the learning process itself rather than the content of the course.
Michele Johnson	Trinity University	Student Success in Integrative Introductory Biology		To help students understand that biological phenomena are the result of the integration of processes at all levels of biological organization, from molecules to ecosystems.
Jose Perez-Jimenez	Universidad del Turabo	PRIMER: Authentic Research on Environmental Microbiology	Yomarie Bernier, Universidad del Turabo	To develop research skills and attitudes among undergraduate students that energize them toward academic progress (i.e., retention) and success (i.e., graduation).
Douglas Causey	University of Alaska Anchorage	Using Authentic Research In Uncontrolled Environments	Michael P. Mueller, Lauren A. Caruso, University of Alaska	To determine when authentic research in undergraduate biology education may become too difficult or "too authentic," by offering an experimental course that uses inquiry-driven learning and authentic research as a means for students to apply socioscientific reasoning skills in ecological contexts.
Eileen Lacey	University of California, Berkeley	AIM-UP! Museum-Based Approaches to Undergraduate Education	Joseph A. Cook, University of New Mexico; Stefanie M. Ickert-Bond, University of Alaska; Scott Edwards, Harvard University	To increase awareness of natural history collections as critical resources for undergraduate education by training undergraduates in museum-based research, developing instructional tools based on freely accessible online museum databases, informing educators at nonmuseum institutions regarding the instructional power of museum collections, and interacting with the public to increase awareness of the educational importance of natural-history museums.
Judy Scotchmoor	University of California, Berkeley	Understanding Evolution for Undergraduates		To integrate core concepts and competencies throughout the Understanding Evolution curriculum by facilitating instructors' ability to integrate evolution throughout the biology curriculum, particularly in introductory classes; and to encourage college biology instructors to use pedagogical techniques supported by education research, with a focus on active, student-centered learning.
Wendy Silk	University of California, Davis	Enhancing Science Learning Through the Arts	Merryl Goldberg, California State University	To enhance undergraduate scientific literacy, communication skills, and appreciation of science and scientists through introducing the arts and music into the biology curriculum.
Diane O'Dowd	University of California, Irvine	Discipline-Based Education Researchers (DBERs)—Specialists and Change at Large Research Universities	Adrienne Williams, University of California, Irvine	To develop and test the effect of specific active-learning strategies on student attitudes and learning gains in large lecture classes, train graduate students in how to teach actively while serving as discussion leaders for large biology courses, and promote DBERs in the Schools of Biological Sciences and Physical Sciences.
Erin Sanders	University of California, Los Angeles	Transformative Undergraduate Research Experiences	Jordan Moberg-Parker, Frank Laski, Debra Pires, University of California, Los Angeles	To pilot the Competency-based Research Laboratory Curriculum (CRLC) in two departments, laying the groundwork for all five life science departments to assimilate successful and cost-effective aspects of this instructional model.

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Gabriele Wienhausen	University of California, San Diego	Discovery-Based Learning in Large Enrollment Lab Course		To introduce a research experience as an integral component of biology education, relate abstract concepts in biology to real-world examples, and Illustrate the collaborative nature of science.
Janet Casagrand	University of Colorado Boulder	Blooming Assessments to Evaluate Course Reform Effectiveness	Katharine Semsar, University of Colorado Boulder	To help students gain a higher level of understanding of biology, and not simply memorize facts, through the introduction of evidence-based course reforms such as in-class clicker questions, concept-based homework, and a homework help room to improve learning and understanding without altering course content.
Michael Klymkowsky	University of Colorado Boulder	Designing a Coherent Curriculum in Molecular Biosciences	Melanie M. Cooper, Michigan State University; Erin M. Furtak, University of Colorado Boulder	To develop courses, course materials, curricula, and formative assessments that help students reach a level of disciplinary competence so that they can "think like a scientist."
Jenny Knight	University of Colorado Boulder	Leveraging Change with the Science Education Initiative	Anne-Marie Hoskinson, Teresa Foley, University of Colorado Boulder	To change the culture (among both students and faculty) of undergraduate biology education; to promote critical-thinking, problem-solving, and communication skills among students; to develop teaching methods that foster a deeper understanding of concepts so that students retain and can use what they have learned; and to develop concept and process skills assessments that can be shared nationally.
Lisa Hines	University of Colorado Colorado Springs	An Entry-Level Research Lab at a Primarily Undergraduate Institution (PUI) and a Community College	Thomas D. Wolkow, University of Colorado Colorado Springs	To evaluate whether integrating a yeast genetics research experience into an otherwise traditional introductory laboratory course would increase knowledge as well as enjoyment, at a public PUI and a community college.
John R Jungck	University of Delaware	Problem-Based Learning in Integrated Biology and Chemistry	Deborah E. Allen, University of Delaware	To increase the retention of biology majors who are first-generation students, are members of historically underrepresented groups, or enter with poor mathematics placements, by integrating general biology and general chemistry courses so that more focus is placed on 21st-century lifelong learning skills.
Jennifer Drew	University of Florida	A New Model for a University 2 + 2 STEM Degree Program	Sebastian Galindo-Gonzalez, Eric W. Triplett, University of Florida	To demonstrate the success of a new model for increasing the number and diversity of STEM graduates while upholding high degree standards and maintaining a cutting-edge curriculum.
David Julian	University of Florida	The X-Laboratory: Integrating Biology, Chemistry and Physics	Gabriela Waschewsky, University of Florida	To help students develop a synthetic, cross-disciplinary approach to understanding the natural sciences; engage students in inquiry-based experiments that model modern, authentic research; and train students in the key theoretical and practical skills necessary to participate meaningfully in modern biomedical research as early undergraduates.
Paula Lemons	University of Georgia	Implementing Vision and Change in Introductory Biology	Norris Armstrong, University of Georgia	To improve assessment of student learning by incorporating constructed response questions into very large introductory biology courses; to improve students' study skills and their ability to learn and apply concepts through voluntary, peer-mediated study sessions; to improve students' skills in applying the process of science (i.e., interpreting and analyzing data and constructing evidence-based arguments); and to improve students' comprehension and application of the concepts of evolution and systems.
Kathrin Stanger-Hall	University of Georgia	Transforming Learning with Interactive Animated Case Studies		To help students make the transition to scientific thinking, develop their critical-thinking skills, and integrate their learning within and across traditional disciplinary boundaries.

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Akif Uzman	University of Houston–Downtown	Partnership for Undergraduate Life Sciences Education (PULSE): Organizing to Catalyze Change	Teresa Balser, University of Florida; Loretta Brancaccio-Taras, Kingsborough Community College; Kate Marley, Doane College	To provide mechanisms and tools for departments to use in institutionalizing the principles of Vision and Change.
Jonathan Marcot	University of Illinois	Flipping a High-Enrollment Introductory Biology Lecture	Carla E. Cáceres, Tracey Hickox, University of Illinois	To improve students' depth of understanding and long-term retention of conceptual content, explicitly promote critical-thinking and scientific reasoning skills, encourage the use of quantitative reasoning, promote connections between biology and other disciplines (e.g., physics and chemistry), and provide students with more opportunities to work and learn collaboratively.
Anna Hiatt	University of Kansas	Using Evo-Devo to Implement Change in Upper-Level Courses.	Donald P. French, Oklahoma State University	To develop an inquiry-based activity targeting evo-devo concepts for two upper-level undergraduate biology courses in evolution and embryology, to document changes in student understanding of evo-devo concepts throughout the course of the semester in the two courses, and to recruit faculty to adopt similar practices and activities in their courses.
Christine Broussard	University of La Verne	Integrating Scientific Inquiry and Reasoning Skills (SIRS)		To provide high-impact practices, such as research experiences and the formation of communities of learners, designed to develop scientific inquiry and reasoning skills.
Mary Tyler	University of Maine	Replacing Cookbook with Inquiry While Reaching More Students	Michelle Smith, Farahad Dastoor, Ryan Cowan, Kevin Tracewski, Eleanor Groden, University of Maine	To transform the first-year biology course sequence to improve science literacy, increase retention of students, and influence how upper-level courses are taught, by revising all first-year labs to be inquiry based, collaborative, and relevant to real-world issues, by creating a means of addressing large classes that serve both on-campus and remote-site audiences, and by providing early intervention for at-risk students to improve their success.
Gili Marbach-Ad	University of Maryland	Supporting Reform in Undergraduate Science Through a Disciplinary Teaching and Learning Center	Laura Egan, Katerina V. Thompson, University of Maryland	To provide opportunities for collaboration between science faculty and science education experts, create a structured environment of teaching and learning communities to support faculty in their efforts to identify appropriate content and adopt effective pedagogies, and make training in teaching science part of the standard graduate program alongside training in scientific research.
Byrn Booth Quimby	University of Maryland	Integrated Life Sciences, An Honors Living-Learning Program	Nicole F. Horvath, Todd J. Cooke, University of Maryland	To transform undergraduate biology education through the creation of an honors living-learning program for piloting, assessing, revising, and then disseminating both academic and cocurricular reforms in various disciplines in the life sciences.
Edward Redish	University of Maryland	NEXUS/Physics: Rethinking Physics for Biology Students	C. Bauer, University of New Hampshire; M. Cooper, Michigan State University; M. W. Klymkowsky, University of Colorado Boulder; C. H. Crouch, Swarthmore College; K. L. Carleton, T. J. Cooke, B. W. Dreyfus, B. Geller, J. Giannini, J. Svoboda Gouvea, W. Losert, K. Moore, J. Presson, V. Sawtelle, K. V. Thompson, C. Turpen, University of Maryland	To improve student understanding of basic concepts in introductory biology and chemistry classes that depend on physical ideas and principles, such as chemical bonding, entropic effects, diffusion, and gradient-driven flow; prepare students to make clear and coherent conceptual sense of topics discussed in their upper-division classes; and help them develop a better understanding of the use of mathematical modeling in science.

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Ann C. Smith	University of Maryland	Community Supports STEM Reform Aligned with Faculty Research	G. Marbach-Ad, S. Balcom, J. Buchner, V. Briken, J. DeStefano, N.M. El-Sayed, K. Frauwirth, B. Fredericksen, V. Lee, K. S. McIver, D. Mosser, B. B. Quimby, P. Shields, W. Song, R. Stewart, K. V. Thompson, D. C. Stein, S. Yarwood, University of Maryland	To create a research-intensive undergraduate curriculum informed by best practices in teaching and learning.
Katerina Thompson	University of Maryland	Infusing Quantitative Approaches into the Undergraduate Biology Curriculum		To help students appreciate the essential role of mathematics and statistics in contemporary bioscience research and allow them to become more adept at applying their quantitative reasoning skills to biological problems.
Naomi Wernick	University of Massachusetts Lowell	Developing Freshman Biology		To revise the biology curriculum to include project-based lab courses and active learning in the classroom, as well as to implement the core concepts and competencies outlined in Vision and Change.
Michael Gaines	University of Miami	Teaching and Assessing a Competency Based Science Curriculum	Jane L. Indorf, S. Barry Issenberg, Alex J. Mechaber, University of Miami	To develop case studies based on the Scientific Foundations for Future Physicians (SFFP) and integrate modules designed at NEXUS partner institutions into the Advanced Program for Integrated Science and Math (PRISM).
Phil Myers	University of Michigan	Animal Diversity Web—A Resource for Learning and Teaching	Tanya Dewey, George Hammond, Roger Espinosa, Tricia Jones, University of Michigan	To develop an online database of species biology that students can search to discover patterns and processes and test hypotheses based on them.
Sue Wick	University of Minnesota Twin Cities	Engaging Undergraduates, Current and Future Faculty		To have undergraduates actively engage with biology ("do biology, not just read about it"), to encourage current faculty to experience active-learning strategies so that they can begin to use them in their courses, and to help train the next generation of faculty to embrace effective active-learning strategies.
Tamar Goulet	University of Mississippi	Class Generated Community Clicker Cases	Lainy B. Day, Kristen A. Byler, Kathleen Sullivan, University of Mississippi	To empirically test the efficacy of an alternative technique to lecturing in a large introductory biology course for nonmajors.
Bethany Stone	University of Missouri–Columbia	Group Redesign of a Non-major's Introductory Biology Course	Sarah Bush, Robin Hurst-March, University of Missouri–Columbia	To redesign introductory biology courses to improve learning outcomes in segments on the nature and process of science and on science and society.
Mark Grimes	University of Montana	Clustering and Graphical Approaches to Examine Diversity		To engage more students in different ways than is achieved by the standard lecture-and-regurgitation model.
William Tapprich	University of Nebraska at Omaha	Integrating Bioinformatics Across the Curriculum	Mark A. Pauley, University of Nebraska at Omaha	To integrate inquiry-based, hands-on bioinformatics-focused laboratories across the biology curriculum.
Olivia George	University of New Mexico	Teaching General Biology to Non-majors at a Tribal College	Leyma De Haro, Summer Raines, Salina Torres, Gloriana Trujillo, University of New Mexico; Dorothy Wester, Christopher Harrington, William Adams, Nader Vadiee, Southwestern Indian Polytechnic Institute	To incorporate active-learning, culturally relevant topics into an undergraduate biology curriculum at a federal tribal college to help students become more informed citizens in their communities.

Submitting Author	**Company or Institution**	**Project Title**	**Additional Contributors**	**Summary of Project Goal** (for complete project abstract, see www.visionandchange.org/project-locator/)
Jennifer Ward	University of North Carolina at Asheville	Expanding a Research-Infused Botanical Curriculum	H. David Clarke, Jonathan L. Horton, University of North Carolina at Asheville	To incorporate inquiry-based research experiences into undergraduate plant biology courses , including lower division botany (required of all majors), so that all students have an authentic undergraduate research experience.
Kelly Hogan	University of North Carolina (UNC) at Chapel Hill	Reducing the Achievement Gap Through Course Redesign	Kelly A. Hogan, Jean DeSaix, UNC at Chapel Hill	To create student-centered learning experiences inside and outside of the classroom; help level the playing field for underprepared students; spread the word about student-centered learning to faculty, thereby promoting a campuswide commitment to change; and promote faculty development in the area of student-centered learning.
Gordon Uno	University of Oklahoma	Bringing Change to Introductory Biology Courses in the U.S.		To build a network of scientists, science educators, and instructors who are engaged in the study, delivery, and revision of introductory biology courses all around the country.
Eleanor Vandegrift	University of Oregon	University of Oregon Initiatives Improving Science Education	Judith Eisen, Peter O'Day, Michael Raymer, Mark Carrier, Cristin Hulslander, Ronald Beghetto, Mia Tuan, University of Oregon	To help students reach the core competency of communicating science, cultivate aspects of students' biological literacy, use evidence-based pedagogy in student-centered classrooms, and provide professional development in best teaching practices for current and future faculty.
Sam Donovan	University of Pittsburgh	Problem Spaces: Supporting Student Inquiry Using Online Data		To provide access to engaging and relevant biological phenomena that can be collaboratively investigated by using publicly available research data and analysis tools.
Jean Schmidt	University of Pittsburgh	Redesign of Large Enrollment Introductory Biology Laboratory	Elia Crisucci, University of Pittsburgh	To shift from scripted, single-session lab exercises to inquiry-based projects that run over multiple lab sessions.
Amelia Ahern-Rindell	University of Portland	Evolution: A Capstone Course to Assess Biological Competency		To use the Vision and Change core concepts and competencies to create a cohesive curriculum organized around an encompassing biological theme that provides students with a relevant conceptual framework that supports learning.
Nanette Diffoot	University of Puerto Rico, Mayagüez Campus	Inquiry-Based Lab Exercises in Undergraduate Biology Courses	Vivian Navas, Dimuth Siritunga, Rafael Montalvo, Franklin Carrero-Martinez, Nico Franz, Carlos Acevedo, Ana Velez, University of Puerto Rico, Mayagüez	To integrate inquiry-based laboratory exercises into undergraduate biology courses pipelined across the curriculum and to explore nontraditional approaches to developing research skills.
April Hill	University of Richmond	Integrated Quantitative Science: A Multi-Disciplinary Course		To engage students through an integrated and interdisciplinary course; to enable them to solve real-world problems by using multiple methods, including quantitative and research approaches; to increase the number of students pursuing cross-disciplinary research opportunities; and to increase interdisciplinary understanding and collaboration among faculty.
Gail Wagner	University of South Carolina	Society for Economic Botany		To improve undergraduate teaching excellence, model how interdisciplinarity may enhance science education, and provide open-source, online, peer-reviewed ethnobiological teaching and assessment materials so that even isolated faculty can join a network of other faculty.
Elisabeth Schussler	University of Tennessee, Knoxville	Collaboration and Reform at the University of Tennessee	Anna Jo Auerbach, University of Tennessee	To transform the core curriculum for biology majors to focus more explicitly on the process of science.

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Sarah Simmons	University of Texas at Austin	Teaching through Research: the Freshman Research Initiative	Ruth I. Shear, University of Texas at Austin	To attract and retain students in the sciences; improve undergraduate academic success, science literacy, and critical-thinking skills; bridge the gap between education and research by using research as a vehicle for teaching; create an environment in which the effects of research training can be assessed; drive curriculum reform; and enhance collaborations that promote education through undergraduate research.
Stephen Aley	University of Texas at El Paso	Enabling Student Success: A Learner-Centered Methodology	James E. Becvar, Ann H. Darnell, University of Texas at El Paso	To graduate more students and increase participation of underrepresented students in biomedical research.
James E. Becvar	University of Texas at El Paso	Peer-Led Success Strategy in Large Enrollment Intro Courses	Stephanie Moreno, Ann Darnell, University of Texas at El Paso	To improve understanding of basic concepts in general chemistry, especially those underpinning biological processes; generate student-created learning materials; increase retention; and improve learning strategies relevant to later courses.
Sandra Romano	University of the Virgin Islands	A Certification Program for Vision and Change Recommendations	K. Aguirre, Coastal Carolina University; T. Balser, University of Florida; T. Jack, Dartmouth University; K. Marley, Doane College; K. Miller, Washington University in St. Louis; M. Osgood, University of New Mexico; P. Pape-Lindstrom, Everett Community College	To help departments and institutions use existing and additional new assessment evidence to evaluate progress in departmental and institutional efforts to implement Vision and Change recommendations and create a certification program to serve as a self-assessment tool for departments.
Linda Columbus	University of Virginia (UVA)	Biochemistry Curriculum Initiatives at UVA	John Hawley, University of Virginia	To increase student learning through the design of an integrated and research-based curriculum and the creation of an institutional and national community of faculty.
Sarah Eddy	University of Washington	Class Strategies to Increase Achievement of ALL Students	Sara Brownell, Mary Pat Wenderoth, Alison Crowe, Scott Freeman, University of Washington	To increase the retention and achievement of all students (particularly, historically underrepresented groups) and provide students with opportunities to develop skills in class that are in alignment with the core set of concepts and competencies suggested in Vision and Change.
Kathryn Perez	University of Wisconsin–La Crosse	Evolution across the Biology Curriculum at the University of Wisconsin–La Crosse	Mike Abler, Anita Baines, Lee Baines, Gretchen A. Gerrish, Tisha King Heiden, Anton Sanderfoot, University of Wisconsin–La Crosse	To implement a concerted effort toward teaching evolutionary content across the biology department's core (required) curriculum.
Janet Branchaw	University of Wisconsin–Madison	Models for Change at the University of Wisconsin–Madison	Sarah Miller, Christopher Olsen, University of Wisconsin–Madison	To integrate the Vision and Change recommendations into interventions that directly affect students and into interventions that teach professional development for future faculty and current faculty members.
John Berges	University of Wisconsin–Milwaukee	Piloting an Undergraduate Research Biomathematics Program	Erica Young, Istvan Lauko, Nigel Rothfels, Gabriella Pinter, University of Wisconsin–Milwaukee	To develop a National Science Foundation–supported research program at the interface of undergraduate biology and mathematics that promotes cross-disciplinary education in both disciplines, with a focus on undergraduate research, and that strengthens the culture and academic foundation of interdisciplinary biology–mathematics education.
Karen Klyczek	University of Wisconsin–River Falls	Molecular Biology Simulations for Case Based Learning	Mark Bergland, University of Wisconsin–River Falls	To facilitate case studies and other active-learning strategies via the development of computer simulations of molecular biology lab techniques.
Kim Mogen	University of Wisconsin–River Falls	Adapting a National Model for Freshman Research Experience	Karen Klyczek, University of Wisconsin–River Falls	To infuse authentic research experiences into first-year biology courses in an effort to increase retention in STEM majors and in careers in science.

Submitting Author	**Company or Institution**	**Project Title**	**Additional Contributors**	**Summary of Project Goal** (for complete project abstract, see www.visionandchange.org/project-locator/)
Richard Mankin	U.S. Department of Agriculture, Agricultural Research Service, Center for Medical, Agricultural, and Veterinary Entomology	Internships for Undergraduate Students with Disabilities		To enhance research experiences of undergraduate biology students with disabilities by providing internships at an agricultural research laboratory.
Ann Stevens	Virginia Tech	A New Microbiology Curriculum Based on Vision and Change	Sue Merkel, Cornell University; Amy Chang, American Society for Microbiology	To develop a curriculum that is relevant to both biology majors and students in allied health curricula.
A. Daniel Johnson	Wake Forest University	BioBook: A Flexible Alternative to Traditional Textbooks	Sabrina D. Setaro, The Adapa Project; Jed C. Macosko, Wake Forest University	To develop flexible, scalable alternatives to traditional printed textbooks—alternatives that build on current evidence of best practices, support a variety of instructional models, and adapt to new modalities as they emerge.
William Davis	Washington State University	Raising the PULSE: Inspiring Departments to Utilize Vision and Change	Judy Awong-Taylor, Georgia Gwinnett College; Gita Bangera, Bellevue Community College; Richard Cardullo, University of California, Riverside; Ellen Goldey, Wofford College; Melanie Lee-Brown, Guilford College; Cynthia Peterson, University of Tennessee, Knoxville; April Hill, University of Richmond	To inspire departments to undertake the hard work of transforming their programs, as called for in *Vision and Change in Undergraduate Biology Education: A Call to Action.*
Douglas Chalker	Washington University in St. Louis	Converting Advanced Lab Courses to Research Collaborations	Sarah Elgin, Washington University in St Louis	To provide as many undergraduate research opportunities as possible, with biology laboratory courses structured as investigative experiences in which students undertake original, collaborative research projects.
Sarah C. R. Elgin	Washington University in St Louis	The Genomics Education Partnership: Shared Research		To provide undergraduates with an opportunity to participate in a large-scale genomics research project.
John Geiser	Western Michigan University	Improving Undergraduate Biology via Engagement and Collaboration	Renee Schwartz, Western Michigan University	To enhance the relevance and accessibility of introductory-level biology courses.
Deborah Donovan	Western Washington University	A Research-Based Inquiry Curriculum for the Life Sciences	John Rousseau, Whatcom Community College; Irene Salter, Leslie Atkins, California State University, Chico	To develop a life science curriculum, using a published physics curriculum as a model, that encourages students to develop a deep conceptual understanding of introductory biology topics and creates an environment in which students grapple with experimental evidence and ideas through rich conversations in order to construct the targeted scientific concepts themselves.

Submitting Author	**Company or Institution**	**Project Title**	**Additional Contributors**	**Summary of Project Goal** (for complete project abstract, see www.visionandchange.org/project-locator/)
Stasinos Stavrianeas	Willamette University	Introducing the Northwest Biosciences Consortium (NWBC): Introductory Biology for All Students	Marlene Moore, Willamette University	To achieve student learning outcomes aligned with Vision and Change concepts and competencies by developing a series of customizable modules that can be incorporated into any first-year or introductory biology sequence; by developing course descriptions aligned with Vision and Change that facilitate curriculum design and student transition, especially from 2-year to 4-year institutions; and by using the NWBC to foster professional development, provide support, promote the dissemination of relevant material, and legitimize the need for change at the faculty member's home institution.
Lois Banta	Williams College	Inquiry-Based Genomics Lab Module Collection	Erica J. Crespi, Jodi A. Schwarz, Elizabeth Collins, Kathleen M. Raley-Susman, Marc L. Smith, David Esteban, Vassar College; Susan Singer, Sean Fox, John McDaris, Cathryn A. Manduca, Carleton College; Eliot C. Bush, Harvey Mudd College; Cara M. Constance, Hiram College; Derek Dean, Williams College; Carol Ann Paul, Ginny Quinan, Wellesley College; Christopher S. Wallace, Ginger S. Withers, Whitman College; Ross H. Nehm, Ohio State University; Lynn Caporale, consultant	To address the challenges of helping faculty members integrate genome-scale science into the undergraduate classroom.
Ellen Goldey	Wofford College	Using Scientific Teaching to Transform First Year Biology	William R. Kenan, G.R. Davis, Wofford College	To develop a new course in biological inquiry that adopts the tenets of scientific teaching, uses best pedagogical practices (e.g., guided inquiry, flipped classrooms, team-based learning) and builds the knowledge and competencies called for in Vision and Change.
Harris McFerrin	Xavier University of Louisiana (XULA)	Active Learning and Assessments in XULA Biology Curriculum	Mary C. Carmichael, Shubha K. Ireland, XULA	To introduce more active-learning concepts, coupled with increased assessment, in an effort to improve student outcomes.
Jennifer Frederick	Yale University	Accelerated Transformation at Yale and Beyond	Jo Handelsman, Phineas Rose, Yale University	To transform undergraduate science teaching at colleges and universities across the United States by training faculty, instructors, postdoctoral scholars, and graduate students in teaching and mentoring.
Jo Handelsman	Yale University	The National Academies Scientific Teaching Alliance (NASTA)	Jennifer Frederick, Yale University	To transform undergraduate biology instruction, particularly in large introductory courses, by training university faculty in the principles and practice of research-based teaching.

TABLE 9: Professional Societies and other National Science Foundation Research Coordination Networks in Undergraduate Biology Education (RCN–UBEs)

Since the original Vision and Change national meeting in 2009, many professional societies have helped members improve the teaching and learning of undergraduate biology. This support has included everything from education sessions at annual meetings, to professional development opportunities, to increasing the visibility (and value) of biology-related educational research in prestigious journals. This table provides a quick overview of some of the many activities that are underway in professional societies, as well as those of other RCN-UBE projects that are dedicated to advancing the life sciences on the basis of materials provided by the project leaders. For more information about a particular project, contact the submitting author, c/o his or her organization.

REPRESENTATIVE PROFESSIONAL SOCIETY PROJECTS				
Submitting Author	**Institution or Organization**	**Project Title**	**Additional Contributors**	**Summary of Project Goal**
Susan Musante	American Institute of Biological Sciences	Building Leadership Capacity for Transformational Change	Teresa C. Balser, University of Florida; Charlene D'Avanzo, Hampshire College; and Muriel Poston, Pitzer College	To increase the community's understanding of leadership needs, to gain an understanding of the key elements of effective leadership development programs, and, ultimately, to describe an effective and sustainable program, grounded in research, in order to build faculty's academic leadership skills.
Marsha Lakes Matyas	American Physiological Society	Growing a Physiology Education Community of Practice (PECOP)	Barbara E. Goodman, University of South Dakota Sanford School of Medicine; and Jenny McFarland, Edmonds Community College (WA)	To support increased understanding and the implementation of evidenced-based learning in undergraduate physiology education among both new and established educators, including those who teach diverse populations of students.
Amy L. Chang and Kelly A. Gull	American Society for Microbiology (ASM)	ASM Conference for Undergraduate Educators Promotes Change		To improve teaching and learning in undergraduate biology; identify concepts, understanding, and skills in biology; and develop a robust community of practice.
Education Committee	American Society of Plant Biologists	How a Scientific Society Promotes and Supports Change		To generate a set of plant biology core concepts and learning objectives consistent with Vision and Change.
Elizabeth A. Ruedi	Genetics Society of America (GSA)	Genetics Society of America Peer-Reviewed Education Resource Portal (GSA PREP)		To provide an outlet for GSA members to publish and access peer-reviewed educational resources that follow the principles of Vision and Change and exemplify inquiry-based learning.
Bob Podolsky	Society for Integrative & Comparative Biology (SICB)	Revitalizing the SICB Educational Mission		To incorporate the goals of Vision and Change into each of the diverse teaching disciplines represented by SICB and promote best practices in science education.
Robert T. Pennock	Society for the Study of Evolution (SSE)	Small Grants Program for Local and Regional Outreach Promoting the Understanding of Evolutionary Biology		To provide funds for SSE members for outreach projects that further the goals of Vision and Change.

ADDITIONAL VISION AND CHANGE–RELATED PROJECTS (e.g., RCN-UBEs)				
Submitting Author	**Institution or Organization**	**Project Title**	**Additional Contributors**	**Summary of Project Goal**
Lori Scott	Augustana College (IL)	Microbial Genome Annotation Network	Cheryl Kerfeld, Lawrence Berkeley National Laboratory; Chris Kvaal, St. Cloud State University; Brad Goodner, Hiram College; Jayna Ditty, University of St. Thomas; Daniela Schroeter and Kristin Hobson, Evaluation Center, Western Michigan University	To train undergraduate and high school faculty in the use of publicly available bioinformatics tools for offering students a contemporary and inexpensive authentic research experience, and to promote an online bioinformatics tool kit used for developing authentic student research in microbial genome analysis and re-annotation.
M. Drew LaMar	College of William and Mary	QUBES: Quantitative Undergraduate Biology Education and Synthesis	Carrie Diaz Eaton, Unity College; Dorothy Belle Poli and Anil Shende, Roanoke College; Robert Sheehy, Radford University; and Eungchun Cho, Kentucky State University	To provide the means to better coordinate multiple efforts in improving quantitative biology education where curriculum content can be created, shared, modified, stored, and organized, all in a heavily social, adaptive, and collaborative context.
Gillian Bowser and Mark Brown	Colorado State University	Rocky Mountain Science and Sustainability Network Academy	Elizabeth Davis, University of New Haven; and Ulrike Gretzel, University of Queensland	To help develop the next generation of diverse science leaders who are prepared to address issues related to environmental and cultural sustainability.
Sue Merkel	Cornell University	A New Concept-Based Curriculum for General Microbiology Based on Vision and Change	Ann M. Stevens, Virginia Tech; and Amy Chang, American Society for Microbiology	To advance Vision and Change recommendations across the microbiological sciences.
Vincent Buonaccorsi	Juniata College (PA)	Vision and Change Through the Genome Consortium for Active Undergraduate Teaching Using Next-Generation Sequencing (GCAT-SEEK)	M. P. Peterson, Penn State; A. Aguilar, California State University, Los Angeles; D. Grove, Penn State University; A. Hunt, University of Kentucky; R. Lamendella, Lawrence National Laboratory; J. Newman, Lycoming Collge; C. Praul, Penn State; T. Tobin, Susquehanna University; N. Trun, Duquesne University; and J. Roney, Juniata College	To bring together a network of schools with the resources necessary to support faculty and undergraduate research projects in genomics.
Loretta Brancaccio-Taras and Amy Chang	Kingsborough Community College (NY) and American Society for Microbiology	Biology Scholars Program Catalyzes Societies Through Empowering Members		To empower biologists to be leaders in science education reform, to support an interactive community of biology scholars committed to evidence-based teaching and the scholarship of teaching and learning, and to catalyze networks among life science professional societies to collectively engage in sustained undergraduate education reform.
Margaret Waterman	Southeast Missouri State University	Science Case Network	Clyde Herreid, State University of New York at Buffalo; Patricia Marsteller, Emory University; Aditi Pai, Spelman College; Mark Bergland and Karen Klyczek, University of Wisconsin–River Falls; Deborah Allen, University of Delaware; Michelle Fisher, EMBRLI Consulting; Bjorn Wolter, Michigan State University; Al Kuslikis, Sr., American Indian Higher Education Consortium; and Alan White, University of South Carolina	To research the effectiveness of case studies and problem-based learning in a wide variety of undergraduate institutional settings and to provide a workspace where individuals (such as faculty educators, administrators, developers, researchers, etc.) using or wanting to use these pedagogies can find key information, opportunities, and support for their work, as well as share their own questions, experiences, and findings.

Submitting Author	Institution or Organization	Project Title	Additional Contributors	Summary of Project Goal
Thomas A. Pressley	U.S. Air Force Academy	Curricular Assessment and Revision at a Military Service Academy	Steven C. M. Hasstedt, Marcus D. King, Katherine L. Bates, Curtis W. Burney, Jennifer C. Guess, and David A. Westmoreland, Department of Biology, U.S. Air Force Academy, Colorado Springs, CO	To provide a modern, rigorous program in the biological sciences while also meeting the institutional mission of preparing future officers for the U.S. Air Force.
Phil Myers and Tanya Dewey	University of Michigan, Museum of Zoology	Enhancing Data Discovery and Usability for Inquiry in Biology Education		To promote student-centered learning in biology through authentic inquiry using real data.
Joseph A. Cook	University of New Mexico, Museum of Southwestern Biology	AIM-UP! Advancing the Integration of Museums into Undergraduate Programs	Scott V. Edwards, Harvard University; Eileen Lacy, University of California, Berkeley; Stefanie Ickert-Bond, University of Alaska; Robert P. Guralnick, University of Colorado Boulder and University of Florida, Gainesville; Kayce Bell, University of New Mexico; Anna Monfils, Central Michigan University; John McCormack, Occidental College; and Libby Ellwood and Austin Mast, Florida State University, Tallahassee.	To develop a network of educators and museum personnel committed to enabling biology education by using the unique resources of natural history collections.
Gordon E. Uno	University of Oklahoma	Introductory Biology Project: Preparing to Prepare the 21st Century Biology Student		To build a network of scientists, science educators, and instructors engaged in the study, delivery, and revision of introductory biology courses all around the country.
Elisabeth Schussler	University of Tennessee, Knoxville	BioTAP: Biology Teaching Assistant Project		To create a network to gather best practices for biology graduate teaching assistants for professional development of their teaching.

Appendix B

2013 Conference Agenda

VISION AND CHANGE IN BIOLOGY UNDERGRADUATE EDUCATION:
CHRONICLING CHANGE, INSPIRING THE FUTURE

August 28 –30, 2013

WEDNESDAY, AUGUST 28, 2013

4:00 – 9:00 p.m.	Registration Open
5:30 p.m.	Welcoming Plenary Session I

Welcome Remarks & Project Objectives

Yolanda S. George, Deputy Director, Education and Human Resources Programs, AAAS

Welcome Remarks & Conference Overview

Moderator, *Carol Brewer*, Cochair, Vision and Change Advisory Board; and Former Associate Dean, Colleges of Arts and Science, and Professor Emerita of Biology, University of Montana

Alan I. Leshner, Chief Executive Officer, AAAS; Executive Publisher, *Science*; and Cochair, Vision and Change Advisory Board) (video remarks)

Susan R. Singer, Division Director, Division of Undergraduate Education, Directorate for Education and Human Resources, NSF

Speaker, *Mark Becker,* President, Georgia State University

6:45 p.m.	**Reception and Poster Session I** Meet and mingle with the colleagues with whom you will be working throughout the Conference. View posters and enjoy a buffet dinner and cash bar.
8:15 p.m.	Organizational Meeting for Working Groups Up to 75 participants in each work group topical area. Each topical group will break up into three working subgroups for the focused work of the meeting. Each subgroup will have three facilitators. Topical areas are as follows: 1. How to Lead Change 2. How to Be Faculty (Including All Instructional Staff) as Agents of Change 3. How to Change the Student Experience 4. How to Build Networks for Change 5. How to Amass Evidence for Evaluation of Change
9:00 p.m.	Closes for the Day

THURSDAY, AUGUST 29, 2013

7:00 a.m. – 6:00 p.m. Registration continues

7:00 a.m. – 8:00 a.m. Breakfast on your own

8:00 a.m. **Plenary Session II** – Panel Discussion

Welcome Remarks

Cynthia Bauerle, Assistant Director, Undergraduate and Graduate Programs in Science Education, Howard Hughes Medical Institute (HHMI)

Muquarrab Qureshi, Assistant Director, Institute of Youth, Family, and Community, USDA, National Institute of Food and Agriculture (NIFA)

Jon R. Lorsch, Director of the National Institute of General Medical Sciences, National Institutes of Health (NIH)

Joan Ferrini-Mundy, Assistant Director, NSF Education and Human Resources

Driving Educational Change

Moderator: *Shirley Malcom,* AAAS, Director, Education and Human Resources Programs

Lorelle Espinosa, Senior Analyst at Abt Associates

Thomas J. LeBlanc, Executive Vice President and Provost, University of Miami

Mary Ann Rankin, Senior Vice President and Provost, and Professor of Biology, University of Maryland, College Park

Robert P. Elde, Dean, College of Biological Sciences, University of Minnesota, and J. B. Johnston Land Grant Professor of Neuroscience

Four, 15-minute presentations with moderated question and answer. Each speaker talks about how he or she knows that change is occurring and about the direction of the change.

10:00 a.m. Break

10:15 a.m. Meeting Time for Working Subgroups

12:15 p.m. Lunch and Keynote Plenary Address

Moderator, *Carol Brewer,* Cochair, Vision and Change

Speaker, *James Collins,* Virginia M. Ullman Professor of Natural History and the Environment, Arizona State University

2:15 p.m. **Poster Session II**

3:45 p.m. Break

4:00 p.m. Last Session of Working Subgroups: Prepare Three slides for Friday's Plenary Session

6:00 pm Dinner on Your Own and Poster Removal

FRIDAY, AUGUST 30, 2013

7:00 a.m.	Hot Breakfast
8:00 a.m.	Last Meeting of Working Subgroups: Next steps for Finalizing Work Products (All the Subgroups in a Topic Area)
9:00 a.m.	**Plenary Session III** **Moderator, *Carol Brewer,*** Cochair Reports from the Working Subgroups within Each Topical Area
5 minutes for up to 15 working subgroups	
10:30 a.m.	Synthesis for Action *Muriel E. Poston,* Professor of Biology, Vice President for Academic Affairs, and Dean of Faculty, Pitzer College *Maria Elena Zavala,* Professor of Biology, California State University, Northridge
11:30 a.m.	Next Steps and Charge to the Community **Moderator, *Carol Brewer*** About PULSE and *CourseSource* (10 minutes total) Remarks from Agency Representatives
12:15 p.m.	Conference Adjourns

(Postconference debriefing for advisors and facilitators only, 12:30 p.m.–4:00 p.m.)

ACKNOWLEDGMENTS

Dear Colleagues:

The AAAS Vision and Change (V&C) in Undergraduate Biology Education: Chronicling the Change Initiative sought to take stock of what has been accomplished at both the course and faculty level since the start of the V&C initiative in 2006 and to consider how to accomplish the larger scale changes needed at the departmental and institutional levels. We were particularly interested in actions related to the V&C 2011 report.

This report would not have been possible without the response from over 500 faculty and staff at 292 colleges and universities, professional societies, and other institutions who submitted abstracts, responded to questions, and/or presented posters at the 2013 follow-up conference about the efforts they are making to change undergraduate biology education at their institutions.

Also, we are most appreciative to the 51 individuals who agreed to serve as facilitators for the conference working subgroups and who helped to identify shared challenges and recommendations for continued change and leadership in undergraduate biology.

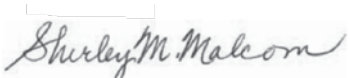
We would like to thank our supporters and partners who were instrumental in planning this conference, including the NSF; HHMI; NIH, NIGMS; and USDA's NIFA. We are especially grateful to the Vision and Change Advisory Board, led by Carol Brewer, cochair of the board; and former associate dean, College of Arts and Sciences, and professor emerita of biology, University of Montana; and Alan I. Leshner, Chief Executive Officer Emeritus, AAAS and executive publisher of *Science* magazine.

This report would not be possible without the diligence of the editor, Diane Smith, who stepped in and pulled together information from the abstracts and conference recordings and facilitator notes. Finally, we would like to thank Brian Baker (copy editor), Tarrick Clayton (AAAS coordinator), and Gail Peck (graphic design, peckstudios.net) for helping to finalize the report.

We hope this follow-up report and related materials will give you even more ideas and strategies as you go about your work to transform your institutions to better prepare undergraduate STEM majors and nonmajors to meet the biology-related challenges of the 21st century.

Best Regards,

Yolanda S. George,
Deputy Director,
Education and Human Resources Programs (EHR),
AAAS



Shirley M. Malcom,
Director EHR,
AAAS

For more information on the AAAS Vision and Change in Undergraduate Biology Education Initiative, see www.visionandchange.org.

This report is on the website at http://visionandchange.org/chronicling-change/.

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