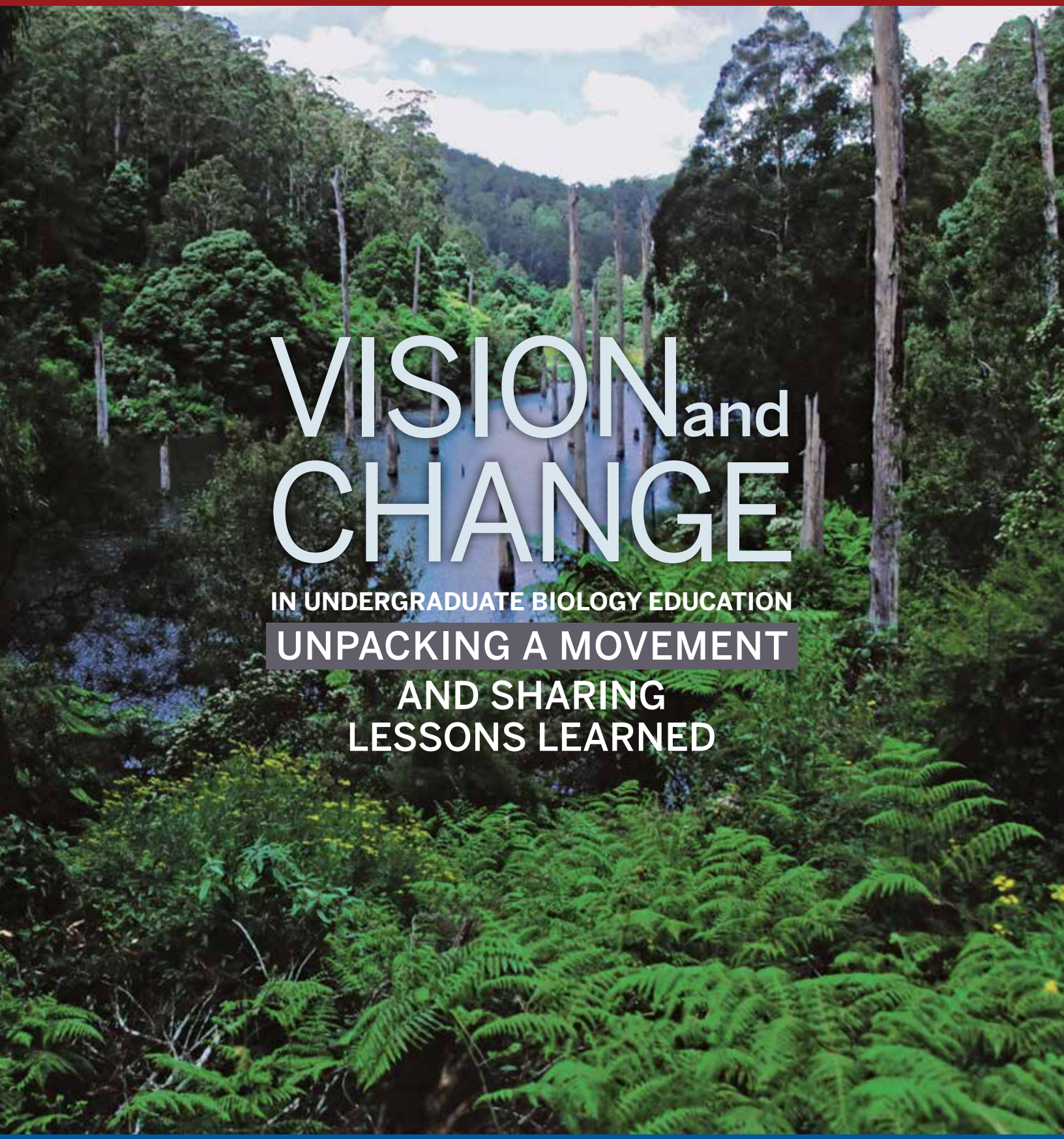

VISION and CHANGE

IN UNDERGRADUATE BIOLOGY EDUCATION

UNPACKING A MOVEMENT AND SHARING LESSONS LEARNED

www.visionandchange.org

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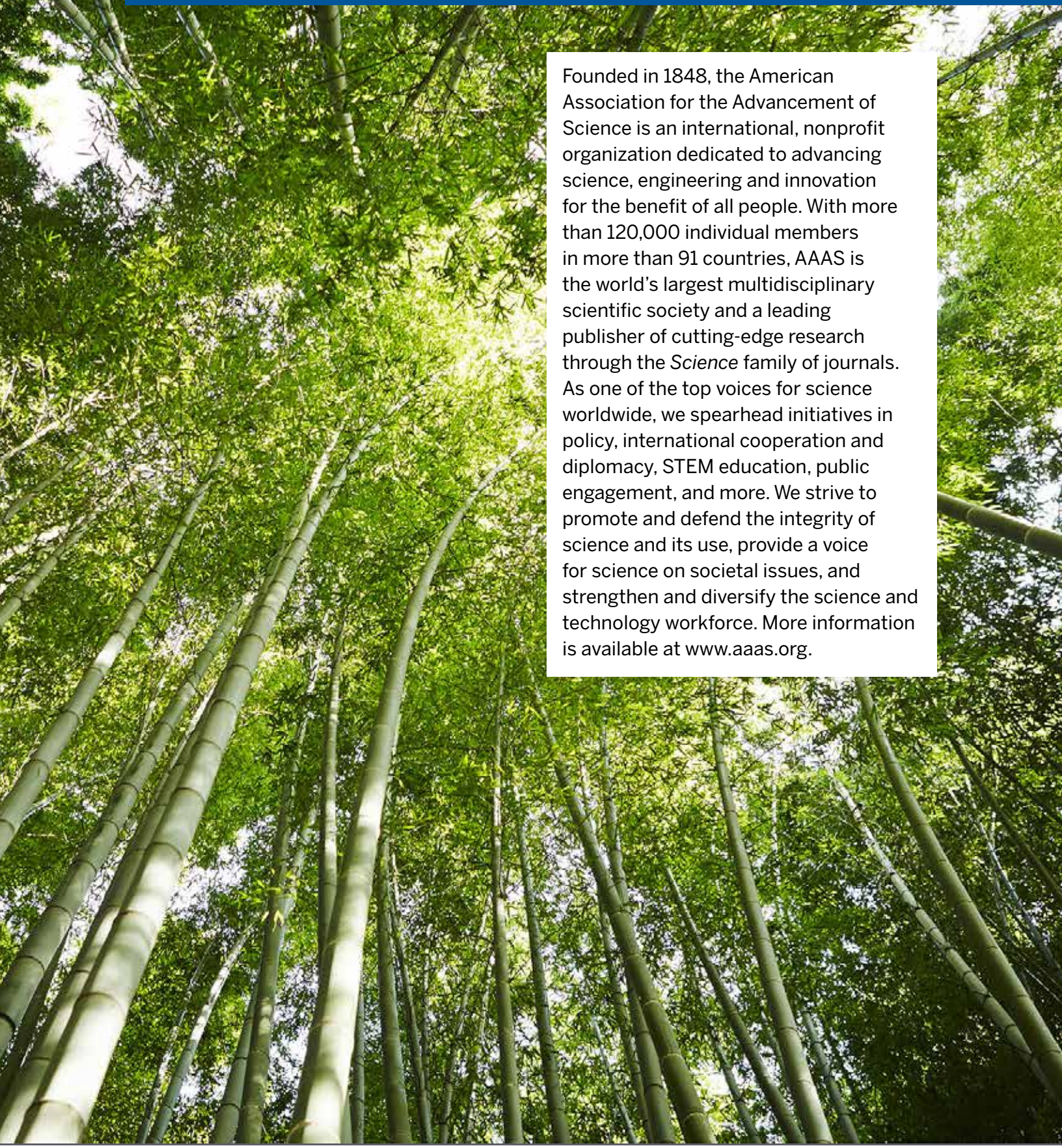
About AAAS



Founded in 1848, the American Association for the Advancement of Science is an international, nonprofit organization dedicated to advancing science, engineering and innovation for the benefit of all people. With more than 120,000 individual members in more than 91 countries, AAAS is the world's largest multidisciplinary scientific society and a leading publisher of cutting-edge research through the *Science* family of journals. As one of the top voices for science worldwide, we spearhead initiatives in policy, international cooperation and diplomacy, STEM education, public engagement, and more. We strive to promote and defend the integrity of science and its use, provide a voice for science on societal issues, and strengthen and diversify the science and technology workforce. More information is available at www.aaas.org.

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VISION and CHANGE

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AMERICAN ASSOCIATION FOR THE
ADVANCEMENT OF SCIENCE

with support from the

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

Report prepared by
Ann E. Austin, Michigan State University

Editor
Diane Smith

This publication is dedicated to Yolanda George, deputy director for Education at AAAS, who has steered the Vision & Change initiative since its inception.

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

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VISION & CHANGE

IN UNDERGRADUATE BIOLOGY EDUCATION

UNPACKING A MOVEMENT AND SHARING LESSONS LEARNED

PLANNING MEETING, BOSTON, MASSACHUSETTS, JULY 9, 2017

MEETING REPORT

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LETTER FROM TERRY WOODIN

This is an exciting time in biology undergraduate education. There are increasing calls for change by prominent scientists, professional societies, and funding agencies. A series of publications and workshops have been produced to help faculty, departments, and universities effect that change. Among the changes advocated is a conceptual, active learning teaching approach, which leads to greater student engagement, discussion, and reflection—developing, not stuffing, minds. The observed increase in the hiring of a new class of biologists, discipline-based education researchers, promises improvement at the grassroots level.

But all of these changes lead to the question of how deeply these calls for change have affected the undergraduate biology community, and what the outcomes have been of adapting these changes. *Vision & Change: Unpacking a Movement and Sharing Lessons Learned* is a document designed to stimulate thinking and action on such questions. This is a crucial endeavor if we are to succeed in this important and complex change effort.

PUTTING THINGS IN CONTEXT

Vision & Change is now almost 20 years old. It is the grandchild of calls for change to both curriculum and teaching approaches advanced by John Moore in the 1980s, most prominently in a seminal article in *American Zoologist* calling for a dynamic, conceptual approach to science education.[1] He asserted that students, faculty, departments, universities, and the nation would benefit from such an approach and he urged greater attention by scientists to this matter, as well as greater respect for science education efforts on university and K-12 campuses. His article not only stimulated widespread discussion, but it also led to a series of efforts by prominent biologists to design ways to improve biology education to be more dynamic and representative of the evolving nature of the discipline. These efforts have included a series of publications with specific suggestions outlining how faculty, departments, and universities can respond to the calls for change,[2,3,4] along with the establishment of related faculty workshops and institutes, most of which are still ongoing. It is important to note that each of these efforts was fueled by prominent scientists who saw the need for the change and felt the time had come to start implementing it. Moreover, each provided fertile ideas for the efforts that followed, with most depending on voices from the field to produce consensus documents setting out the needs for improving undergraduate biology and ways to meet those needs.

1 Moore, J. (1984). Science as a Way of Knowing. *American Zoologist, 24,* 467-534.
2 National Research Council (NRC). (2003). *Bio 2010: Transforming undergraduate education for future research biologists.* Washington, D.C.: National Academies Press.
3 Uno, G. (1999). *Handbook on Teaching Undergraduate Science Courses: A Survival Training Manual.* Thompson Custom Printing www.ou.edu/cas/botany-micro/faculty/uno-book.shtml.
4 Handelsman, J., Miller, S., and Pfund, C. (2007). *Scientific teaching.* New York: W.H. Freeman.

SPECIFICS ABOUT *VISION & CHANGE* AND WHY THE UNPACKING MEETING

To achieve the initial goal and driving philosophy behind *Vision & Change,* organizers designed a series of meetings where conversations among biologists, biology education researchers, and practitioners (representing all fields of the discipline and a variety of institutional types) exchanged ideas about what needs to be done to improve undergraduate biology education and how to do it. From that, the initiative produced a series of documents to help advance biology education to better serve all stakeholders, from students and faculty to universities and the nation itself. The first *Vision & Change* document concerned setting the vision and inspiring the change,[5] while the second chronicled changes called for in the first document.[6]

As a result of these two documents, there has been a general impression that *Vision & Change* efforts have achieved some success, but to date we have lacked objective, quantifiable measures to confirm or deny that impression. So, questions remain: How effective have these efforts been? How deeply have they penetrated the community? How have *Vision & Change* suggestions been disseminated, accepted, and adapted? What have been the outcomes of that adaption? This third document continues in the spirit and design of the first two. But it is unique not only for its concentration on determining outcomes, but also because 1) the document contains no conclusions, only a set of ideas concerning next steps, and 2) a new set of experts—researchers in the field of educational change at the university level—have been added to the discussants involved.

The resulting document calls upon the broader university research and education community to help the *Vision & Change* initiative determine outcomes of change efforts nationwide. It contains ideas generated at a meeting of prominent biologists, biology education practitioners and researchers, and others interested in studying change in higher education, who came together to discuss how best to determine the outcomes of a movement such as *Vision & Change*. Hopefully, it will stimulate research in the field of educational change that will not only inform a large number of hard-working people of the outcomes of their efforts to effect change, but also lead to more effective future change efforts.

5 American Association for the Advancement of Science (AAAS). (2011). *Vision and Change in Undergraduate Biology Education: A Call to Action.* Washington, D.C.

6 American Association for the Advancement of Science (AAAS). (2015). *Vision and Change in Undergraduate Biology Education: Chronicling Change, Inspiring the Future.* Washington, D.C.

I urge you to read it, take its suggestions to heart and, if you are a researcher, use the ideas presented to fuel your research and inform the various communities involved.

WHAT MAY FOLLOW

This biology-focused effort has already drawn interest from scientists in other disciplines who note the need for developing more engaging and effective teaching approaches that reflect advances within their own disciplines, within educational research concerning the sciences, and with modern tools for supporting changed approaches to teaching. The American Association for the Advancement of Science is currently exploring such efforts with the *Levers for Change*[7] project, which will examine effective mechanisms for reform in STEM instruction across multiple disciplines. Ideas from *Unpacking a Movement*, and the papers we hope will follow from it, should help the *Levers for Change* effort as well.

Terry Woodin
Former NSF Program Officer
Champion of *Vision & Change*

7 American Association for the Advancement of Science (AAAS). (2018). *In prep*. See also https://academic-change.org/2018/05/09/were-gonna-need-a-bigger-lever/.

SUMMARY:
VISION & CHANGE UNPACKING A MOVEMENT

PLANNING MEETING | JULY 9, 2017 | EMBASSY SUITES BOSTON AT LOGAN AIRPORT

REPORT SUMMARY

Vision & Change in Undergraduate Biology Education (Vision & Change, or *V&C)* is a seminal consensus document concerning the need to change biology education so that it better represents changes in the discipline. It provides a blueprint for change in teaching approaches across a broad range of institutions and subfields. The purpose of this meeting was to unpack the V&C movement in terms of both the degree of penetration across the discipline, and the impact and results of adapting the principles laid out in the document. The planning meeting was designed to help participants develop working hypotheses about the impact of *Vision & Change*, to identify relevant stakeholders who may have perspectives about the impact, and to brainstorm possible relevant data and methods for collecting and analyzing relevant data.

DISCUSSION 1: OVERALL IMPACT OF *VISION & CHANGE*

The consensus among the participants was that, while *V&C* has probably had an impact in various important ways, we do not yet have a good sense of the extent of that impact as it concerns faculty, departments, and professional societies. While acknowledging the limits of their knowledge of the document's general impact and of the challenges of assessing such impact, the participants also noted specific examples of how *V&C* has made a difference in the field of biology. These include: providing a "framework," a "structure," or an "organizing principle" for encouraging reform in undergraduate biology education; serving as a "touchstone" to which curricular planning efforts and grant proposals can be connected; providing "legitimacy," "validation," and "permission" for faculty to emphasize depth over breadth in their teaching and for department chairs to convene discussions about educational reform; contributing to the creation of a "sense of community" where those interested in improving education in biology can find others of like mind; helping to create a "shared language" that facilitates interdisciplinary conversations about common concepts and science practices; and serving as an "equalizer" in the relationships between institutional types.

DISCUSSION 2: IDENTIFYING STAKEHOLDERS AND TOUCHPOINTS

Participants identified stakeholders with knowledge and perspectives on the impact and penetration of *V&C,* and the ways in which *V&C* is important to these stakeholders. The identified stakeholders fell into five categories: (1) stakeholders within higher education institutions (e.g., faculty, students); (2) stakeholders in the scholarly context (e.g., professional and scholarly societies); (3) educational institutions (e.g., community colleges to research intensive universities); (4) policy organizations and funding agencies (e.g., private and federal funders, accrediting bodies); and (5) other stakeholders.

DISCUSSION 3: DEVELOPING HYPOTHESES

Participants brainstormed hypotheses about the impact of *V&C,* how this impact has occurred, and relevant evidence for it (e.g., anecdotes, stories, examples, qualitative or quantitative indicators). Six themes developed, within which more than 20 specific hypotheses were articulated: (1) impact on changes in mission, curriculum, teaching approaches, disciplinary and educational research, and policy; (2) impact on equity, diversity, and inclusion; (3) impact on the promotion of network development and collaboration; (4) impact on students' attitudes and learning; (5) impact on faculty hiring and development; and (6) impact on the scholarship of teaching and learning and on disciplinary scholarly involvement.

DISCUSSION 4: BRAINSTORMING EVIDENCE

Further discussion focused on what evidence would be relevant to substantiate claims about impact. The discussion was organized around evidence pertaining to the impact of *Vision & Change* on (1) diversity, inclusion, and equity; (2) two-year to four-year transition; (3) active learning resources; (4) student attitudes toward science and technology; (5) college/department missions and values; and (6) curricular reform and educational practices.

INTRODUCTION:

Framing the Meeting

PLANNING MEETING | JULY 9, 2017 | EMBASSY SUITES BOSTON AT LOGAN AIRPORT

MEETING REPORT | PREPARED BY ANN E. AUSTIN

Vision & Change in Undergraduate Biology Education (Vision & Change, or *V&C)* is a seminal consensus document concerning the need to change biology education so that it better represents changes in the discipline. It provides a blueprint for change in teaching approaches across a broad range of institutions and subfields. The purpose of this meeting was to unpack the *V&C* movement in terms of both the degree of penetration across the discipline, and the impact and results of adapting the principles laid out in the document. The planning meeting was designed to help participants develop working hypotheses about the impact of *Vision & Change,* identify relevant stakeholders who may have perspectives about the impact, and brainstorm possible relevant data and methods for collecting and analyzing relevant data.

The meeting was designed to provide a good base of ideas that will be used in the coming months to inform the development of a systematic study of the impact of *Vision & Change.* Examining these challenging questions using the lens of *V&C* may also open avenues for considering, in the future, the outcomes of similar efforts across other science, technology, engineering, and mathematics (STEM) disciplines. Participants were invited on the basis of their diverse positions in relationship to undergraduate biology education and *Vision & Change.* A list of participants is included at the end of this report.

STRUCTURE OF THE REPORT

This report summarizes the comments and discussions that occurred across the day-long meeting. The report is organized to follow the structure of the meeting, which involved four discussions. Each discussion was guided by a set of questions, and participants were divided into small groups to discuss their responses to the questions. The groups had opportunities to summarize and report their key points to the full group. This report summarizes the key points made in each discussion period. The small discussion groups sometimes focused on different aspects of the questions; thus, the summary notes reflect the variation in the nature and focus of the responses to each set of questions. The report represents, as accurately as possible, the tone and substance of the discussions at the meeting. At the same time, some points have been organized as a table or summarized in order to produce a succinct and focused report.

INTRODUCTORY COMMENTS

Beth Ruedi, project director for the American Association for the Advancement of Science (AAAS), welcomed the participants to this important conversation about the impact of *Vision & Change*. And as noted by Terry Woodin, senior advisor to *Vision & Change*, the meeting provided an opportunity to explore how to determine the impact of *Vision & Change*. For example, she asked, "How many people are aware of the report, have read it, and have incorporated *Vision & Change* into their work? What is the effect

on students in terms of knowledge and skills gained? And how do we determine the effect?" Woodin concluded, "We need to find ways to answer these questions and to put the study in the context of attempts by other STEM disciplines to modernize undergraduate education in their fields."

Shirley Malcom, head of the Education and Human Resources directorate at AAAS, reminded participants that the process of engaging in systemic change in biology education started in the early 1990s. The process involved a number of people who needed to frame a common goal and find a way forward—and the way forward resulted in *Vision & Change*. Other fields have asked how the field of biology did this challenging work; they should not expect an easy road. "Changing culture takes a long time," Malcom said, "but it can happen. We need to consider how to measure the change in diversity. We also need to identify appropriate metrics for measuring the impact of *Vision & Change*."

DISCUSSION 1:

Overall Impact of *Vision & Change*

GUIDING QUESTIONS:

- ***To what extent and in what ways has* Vision & Change *penetrated biology departments, and what impact has it had on undergraduate education?***
- ***To what extent and in what ways is reform in undergraduate education occurring in biology, and what has been the role of* Vision & Change *in that reform?***

Participants were organized into small discussion groups that were diverse in terms of the perspectives represented. Each group was a mix of people from different perspectives, including, for example, faculty members, institutional leaders, policymakers, association leaders, and representatives of funding organizations.

The consensus among the participants was that *Vision & Change* has had an impact in various important ways, but that its ideas have not yet been fully implemented. As one participant explained, "There are points of light, but not deep penetration into the core of the faculty." Some teachers and researchers in the field are not aware of *Vision & Change*, and finding instances where entire departments have been changed is difficult. However, while acknowledging the limits of the document's impact and the challenges of assessing such impact, the participants also asserted some noteworthy ways in which *Vision & Change* has made a difference in the field of biology. While each participant could cite examples of changes inspired by *V&C*, they agreed that obtaining quantitative data concerning *V&C*'s impact across the field of biology will be difficult.

GROWING AWARENESS

Over the past five years, meeting participants asserted, awareness of *Vision & Change* has grown. While they were unsure about the extent to which the ideas of *Vision & Change* have been integrated into courses or departmental curricula, participants were firm in asserting that it is making a difference overall in the field of biology. They stated that it provides a "framework," a "structure," or an "organizing principle," and has set expectations and goals for those committed to reform in undergraduate biology education. It also serves as a "touchstone" to which curricular planning efforts, grant proposals, and articles can be connected.

According to participants, authors of grant proposals to the National Science Foundation and other funders usually reference *Vision & Change*, and citations of *Vision & Change* appear regularly in the journal *CBE—Life Sciences Education.* Some participants noted, however, that the interest may sometimes focus more on the competencies highlighted by *Vision & Change*, rather than on the concepts. Some participants noted that *Vision & Change* serves as a "buzz-word" that efficiently conveys a constellation of ideas about teaching and learning. Additionally, referencing *Vision & Change* gives "legitimacy," "validation," and "permission" for faculty to

emphasize depth over breadth in their teaching, and for department chairs to convene curricular discussions about reforming undergraduate education.

A SENSE OF COMMUNITY

Of considerable importance is the way in which *Vision & Change* has contributed to the creation of a "sense of community," enabling those interested in improving education in biology to, in the words of a participant, "find your people." The document has helped to create a "shared language" that facilitates conversations about common concepts and science practices, and enables interdisciplinary conversations. As one participant explained, "The document gives me authority, pulling points that people can relate to... [it's] a great tool that can be further leveraged."

Vision & Change has also served as an "equalizer" in the relationships between institutional types, according to some participants. Faculty and leaders from community colleges can be equal partners with their counterparts in four-year institutions when discussing shared goals, as argued in *V&C*, for undergraduate learning. Furthermore, the ideas of *Vision & Change* are having some impact on the nature and content of transfer and articulation agreements.

***"Changing culture takes a long time, but it can happen. We need to consider how to measure the change in diversity. We also need to identify appropriate metrics for measuring the impact of* Vision & Change."**

TYPES OF IMPACT

In addition to summarizing the overall impact of *Vision & Change*, participants offered specific examples of the types of impact. Some asserted that curricular planning in some departments involves mapping structures and course offerings against *V&C*. Some suggested that *V&C* has inspired changes in courses to emphasize depth over breadth, but overall, participants saw such changes as more likely to occur in lower-level courses and courses for non-majors. Participants also observed that textbook publishers and vendors are, in some instances, aligning their resources with *Vision & Change*. Several participants observed that other disciplines, physics in particular, are using *Vision & Change* to promote their own change processes. Another example of impact, according to some, is the increasing expectation in some departments that applicants for faculty positions should demonstrate their commitment to evidence-based teaching approaches, and that evaluations for promotion should consider the use of evidence-based teaching practices.

A few specific examples were offered to illustrate the ways in which *V&C* is making an impact. The work of the biology Partnership for Undergraduate Life Sciences Education (PULSE) Fellows was highlighted several times throughout the meeting, with recognition of the involvement of PULSE Fellows in providing guidance to departments engaged in curricular reform, including developing and providing rubrics. One participant noted that new faculty members at Washington State University's College of Veterinary Medicine find a copy of *Vision & Change* on their desks on their first day of work. Another participant observed that *V&C* has informed extensive reform in undergraduate courses in biology at Michigan State University.

ASSESSING IMPACT

While offering examples of how *Vision & Change* is making a difference, participants also recognized the challenge of assessing such impact. They observed that analysis of "penetration" should consider various levels, including the individual faculty member, the department, the institution, and the discipline. Furthermore, impact and penetration vary, they asserted, by region and campus, as well as by sub-field in biology. They observed that it is hard to identify or find national data that would speak definitively to the use, implementation, and adaptation of *Vision & Change*. They also mused that impact might be assessed across a scale of levels of "awareness" and a scale of levels of "implementation," and they mused about what might be "markers" of awareness or implementation. Other observations were that analysis of the impact of *V&C* should consider specific "communities" that have been affected and influenced perhaps in different ways; more specifically, the impact may be different on introductory courses versus electives, and on the experiences of biology majors versus the experiences of non-majors.

OTHER CONTRIBUTIONS TO CHANGE

Workshop participants recognized that various other national developments and initiatives have also been occurring and that these initiatives interweave with *Vision & Change* as factors contributing to change in undergraduate biology education (see sidebar). Major national initiatives, such as the Association of American Universities

(AAU) STEM Initiative, the Association of American Colleges & Universities (AAC&U) Leap Challenge, the Next Generation Science Standards, and the Association of American Medical Colleges (AAMC) Foundations for Future Physicians Programs, are organizing national conversations and framing influential ideas. Major programmatic initiatives, such as the Research Coordination Networks in Undergraduate Biology Education (RCN-UBE) programs, Course-based Undergraduate Research Experiences (CUREs), and the Howard Hughes Medical Institute's (HHMI) Inclusive Excellence Program are inspiring significant institutional reform efforts. Initiatives such as the Gordon Research Conferences (GRC), Society for the Advancement of Biology Education Research (SABER), Cottrell Scholars, and PULSE Ambassador Program are convening teachers, researchers, and institutional leaders who are committed to reforming undergraduate education.

Discipline-Based Education Research (DBER) scholars, often situated in academic departments, are framing questions and presenting findings that inform decisions about courses, teaching, and curricular sequences. Programs such as the Center for the Integration of Research, Teaching, and Learning (CIRTL) are preparing future faculty with commitment to and knowledge of evidence-based teaching practices. The Summer Institutes on Scientific Teaching preceded *V&C* but has embraced its ideas and is promoting it in its sessions. The needs and interests of students themselves are leading to departmental discussions about teaching and learning. Each of these developments is effecting change in undergraduate education, making it difficult to specify the precise impact of *Vision & Change*.

Overall, however, while acknowledging the difficulty of teasing out the specific role of *Vision & Change*, the workshop participants recognized and articulated their sense that *V&C* has been an important factor in advancing educational change in biology. Woven throughout their discussions were some thoughtful remarks about the future of *Vision & Change*, including whether it is a "timeless document" or "a stepping stone." Should it be revisited and, in particular, are any adjustments needed in the competencies? Some warned also about the potential danger of faculty acknowledging *Vision & Change* without actually changing.

Vision & Change Advocates and Other Sources of Information

The following provides a list of many of the programs, organizations, initiatives, and approaches referenced in this report, with links when available.

American Association of Community Colleges (AACC)
www.aacc.nche.edu

Association of American Universities (AAU) STEM Initiative
www.aau.edu

Association of American Colleges & Universities (AAC&U) Leap Challenge
www.aacu.org/leap

Association of Public & Land-grant Universities (APLU)
www.aplu.org

Association of American Medical Colleges (AAMC) Scientific Foundations for Future Physicians
www.aamc.org

The American Council on Education (ACE)
www.acenet.edu

American Educational Research Association (AERA)
www.aera.net

Association for the Study of Higher Education (ASHE)
www.ashe.ws

Association Supporting Computer Users in Education (ASCUE)
ascue.org

Bloom's Taxonomy
www.bloomstaxonomy.org

CBE-Life Science Education
www.lifescied.org

Center for the Integration of Research, Teaching and Learning (CIRTL)
www.cirtl.net

Community College Undergraduate Research Initiative (CCURI)
www.ccuri.org

Classroom Observation Protocol for Undergraduate STEM (COPUS)
www.lifescied.org/doi/10.1187/cbe.13-08-0154

Cottrell Scholars
www.rescorp.org/cottrell-scholars

VISION & CHANGE ADVOCATES AND OTHER SOURCES OF INFORMATION

Council of Independent Colleges (CIC)
www.cic.edu

Course-based Undergraduate Research Experiences (CUREs)
www.nap.edu
serc.carleton.edu/curenet

CourseSource
www.coursesource.org

Decibel Analysis for Research in Teaching (DART)
sepaldart.herokuapp.com

Discipline-Based Education Research (DBER)
www.nap.edu

EAB
www.eab.com

Genome Consortium for Active Teaching (GCAT)
www.bio.davidson.edu/GCAT

Genome Education Partnership (GEP)
www.gep.wustl.edu

Gordon Research Conferences - Undergraduate Biology Education Research (GRC-UBER)
www.grc.org/undergraduate-biology-education-research-conference

Howard Hughes Medical Institute (HHMI)
www.hhmi.org

Inclusive Excellence Program – HHMI
www.hhmi.org/developing-scientists/inclusive-excellence

Journal of Microbiology and Biology Education (JMBE)
www.asmscience.org/content/journal/jmbe

Medical College Admission Test (MCAT)
students-residents.aamc.org

National Study of Postsecondary Faculty (NSOPF)
www.nces.ed.gov/surveys/nsopf

Network of STEM Education Centers (NSEC)
serc.carleton.edu/StemEdCenters

Next Generation Science Standards
www.nextgenscience.org

Predictive Analytics Reporting (PAR) Framework
www.parframework.org

VISION & CHANGE ADVOCATES AND OTHER SOURCES OF INFORMATION

Partnership for Undergraduate Life Sciences Education (PULSE) Ambassador Program
www.pulsecommunity.org

Professional Societies Alliance for Life Sciences Education (PSALSE)
www.psalse.org

Project Kaleidoscope (PKAL) Leadership Institute
www.aacu.org/summerinstitutes/sli

Quantitative Undergraduate Biology Education and Synthesis (QUBES)
www.qubeshub.org

Research Coordination Networks in Undergraduate Biology Education (RCN-UBE)
www.nsf.gov

Science Education Alliance-Phage Hunters Advancing Genomics and Evolutionary Science (SEA-PHAGES)
www.seaphages.org

Society for the Advancement of Biology Education Research (SABER)
Summer Institutes on Scientific Teaching
www.summerinstitutes.org

Vertically Integrated Projects (VIP)
www.vip.gatech.edu

DISCUSSION 2:

Identifying Stakeholders and Touchpoints

GUIDING QUESTIONS:

- ***What stakeholders have knowledge and perspectives on the impact and penetration of* Vision & Change?**
- ***How is each stakeholder connected with* Vision & Change*? In what ways is it important or relevant to each stakeholder?***

Participants discussed these questions in the same groups convened for Discussion 1. The discussions about the stakeholders varied in focus and comprehensiveness. Some discussion groups highlighted the kinds of knowledge the particular stakeholder groups would have of *V&C*, or the ways the stakeholder groups would be interested in helping to gather and analyze the impacts of *V&C* as outlined in the table below. Other groups' named stakeholders were listed but not discussed. These included admissions staff, institutional researchers, the discipline-based education research (DBER) community, the informal science education community, the National Academies, Project Kaleidoscope (PKAL) Leadership Institute, parents, online learning communities, the media/journalists, and the general public.

After brainstorming possible stakeholders who would have knowledge and perspectives on *Vision & Change*, and the ways in which these stakeholders are connected with *V&C*, the participants identified the three stakeholders that they thought would be most important in terms of the perspectives they could provide. Faculty had the highest percentage of representation as one of the top three stakeholders (20%), followed by students and administrators/department chairs (both 19%). Professional societies were identified in the top three by 10% of participants, followed by funders and professional societies, both with 6%. Other stakeholders combined also had 20%.

"The* [Vision & Change] *document gives me authority, pulling points that people can relate to... a great tool that can be further leveraged."

TABLE 1

VISION & CHANGE STAKEHOLDERS

HIGHER EDUCATION INSTITUTIONS

Faculty Members: This stakeholder group includes faculty members in all appointment types, including those who are tenured or on the tenure-track, those who are fixed-term faculty, and those who serve in adjunct and/or part-time positions (a group that teaches many undergraduate courses in biology). In addition to faculty who teach biology and science majors, this stakeholder group includes faculty who teach courses for non-majors that may include such topics as science literacy and science in society. All these faculty members can benefit from learning instructional design that is consistent with *V&C*. Research faculty should also be seen as stakeholders. Other faculty to consider as relevant stakeholders are those who serve on tenure and promotion review committees at the college or institutional levels, because, as they review tenure and promotion dossiers, they need to understand the work involved in undergraduate teaching reform.

Undergraduate Students (including majors in biology and other science areas, and non-majors): Undergraduate "buy-in" is needed, as faculty may be reluctant to implement *V&C* ideas and change their teaching and their students' learning processes if they fear poor evaluations. Key issues to consider are student engagement (as *V&C* concepts and competencies are implemented) and the impact of *V&C* implementation on student preparation for graduate school, the MCAT/GRE exams, and the workforce. Online students should be considered as stakeholders as well.

Senior Administrative Leaders (including presidents and provosts): These leaders set the tone for the values and directions of their institutions. The extent and nature of their knowledge and valuing of *Vision & Change* would indicate its role in institutional priorities. They also control institutional budgets that can impact how *V&C* ideas can be implemented.

Graduate Students: Graduate students serve as teaching assistants, and therefore may have knowledge of the use of *Vision & Change* in classrooms. Some graduate students also may be involved in preparation programs for future faculty (such as CIRTL) and may have direct knowledge of the implementation of *V&C* concepts or competencies in courses and classrooms.

Department Chairs: Chairs can either support or impede the integration of *V&C* recommendations into their departments. Their budgetary responsibilities and their role in tenure and promotion decisions mean they can advance or create barriers for the implementation or adaptation of *V&C* ideas.

Postdocs: They are the next generation of faculty, and are often more willing than established faculty members to adopt and advance new ideas.

TABLE 1: VISION & CHANGE STAKEHOLDERS

Faculty Developers/Directors of Centers for Teaching and Learning or STEM Teaching and Learning Centers: These institutional leaders can be involved in designing professional development workshops for faculty, inspired by *V&C*, and may have perspectives on the extent of impact and the implementation of *V&C* concepts.

Student Affairs Professionals and Academic Advisors: These institutional professionals provide advise about courses, and are often involved in guiding students in their first-year experience.

SCHOLARLY CONTEXT

Professional/Scholarly Societies: These disciplinary-focused societies are in a position to promote and disseminate information about *V&C*, create sessions at meetings about *V&C*, and foster consensus about the application of *V&C* to disciplinary sub-disciplines. Leaders of these organizations may have a useful perspective on the extent of impact of *V&C*. Societies of interest include, among others: biology associations, Professional Societies Alliance for Life Sciences Education (PSALSE), Association of American Universities (AAU), Association of American Colleges & Universities (AAC&U), Association of Public & Land-grant Universities (APLU), American Educational Research Association (AERA), the American Association of Community Colleges (AAAC), the Association for the Study of Higher Education (ASHE), and The American Council on Education (ACE).

Disciplinary Journals: A measure of the impact of *V&C* may be the extent to which *V&C*-oriented education research is published in the disciplinary journals.

PULSE Fellows and Other STEM Education Networks: The Partnership for Undergraduate Life Sciences Education (PULSE) Fellows are involved in working directly with departments across the country to encourage the adoption of *V&C* and provide metrics to help departments evaluate their implementation processes. Other networks may include the Biology Scholars Program and the National Academies in Science, Engineering, and Medicine Summer Institutes.

OTHER EDUCATIONAL ORGANIZATIONS

Community Colleges: Some community college faculty are implementing *V&C*, and some articulation agreements between community colleges and four-year institutions are drawing on *V&C* ideas. The use of *V&C* by community college faculty and in articulation agreements would be useful metrics of impact.

Ivy League Universities: These institutions are important stakeholders because they are often referenced as models for other institutions.

For-Profit Higher Education Institutions: It is not clear if *V&C* has permeated the for-profit higher education sector, but this would be an important stakeholder to consider, since many students study in these institutions.

TABLE 1: VISION & CHANGE STAKEHOLDERS

POLICY ORGANIZATIONS AND FUNDING AGENCIES

Government Leaders (local, state, federal, tribal government levels): These leaders have leverage to drive policy around STEM education and employment-related issues.

Funding Agencies: Funders set important policy directions and changes, and provide financial support for *V&C* initiatives. Participants asserted that change and adoption of *V&C* ideas will not happen without the support of funders. Funders' perspectives on where change is happening could be useful.

Accrediting Agencies: Participants raised the question of whether accrediting agencies are looking for active learning as an important feature of high-quality undergraduate education. Also, accreditors play a role in articulating core concepts and learning outcomes, and in establishing perspectives on breadth versus depth in content areas. Some accrediting agencies are interested in competencies, and thus, some have aligned with *V&C* recommendations. The perspectives of those in accrediting agencies inform the impact and spread of *V&C*, and may be useful in examining impact.

OTHER STAKEHOLDERS

Employers: Those employing graduates want to know whether their future employees will have appropriate competencies, including relevant "soft skills." They may have perspectives on the relevance and importance of *V&C*, as well as on its impact. The Business-Higher Education Roundtable may be an important stakeholder to consider.

K-12 Teachers: Both those teaching Advanced Placement (AP) high school courses and those teaching non-AP courses are potential stakeholders. *V&C* relates also to the Next Generation K12 Science Education Standards.

Testing Agencies (such as the Association of American Medical Colleges—AAMC): *V&C* competencies need to be aligned with the Medical College Admission Test (MCAT), since the MCAT is a driver of instruction in undergraduate courses in biology.

Higher Education Consulting and Analytics Organizations: These groups focus on the links between learning and outcomes. Potential stakeholders include: Civitas, Hobsons, Starfish, and EAB.

Textbook Publishers: Publishers may incorporate *V&C* principles, and they may use *V&C* and its integration into their products as a marketing tool.

DISCUSSION 3:

Developing Hypotheses

GUIDING QUESTIONS:

- ***What hypotheses can you offer about the impact of* Vision & Change *on biology departments, and about how this impact has occurred?***
- ***What kinds of evidence (e.g., anecdotes, stories, examples, qualitative or quantitative indicators) currently support your hypotheses?***

For this discussion, participants were asked to break into identity groups (e.g., deans and provosts, faculty members, funding agency representatives, postdocs/doctoral students' disciplinary society representatives). Each discussion group developed several hypotheses and, for each, discussed evidence that would be useful for examining the hypotheses. Once the discussion groups presented their hypotheses to the full group, the hypotheses were grouped by thematic areas, as reported in Table 2 below. The number in parentheses after each hypothesis indicates the number of participants who ranked that hypothesis among the three most important to examine.

"There are points of light, but not deep penetration into the core of the faculty."

TABLE 2

Effects of *Vision & Change* on Undergraduate Biology Education: Hypotheses and Evidence

Suggested hypotheses are grouped into thematic areas, and possible lines of evidence to consider to test the hypotheses are included where discussed. The number in parentheses after each hypothesis indicates the number of participants who ranked that hypothesis among the three most important to examine; null hypotheses are also noted in parentheses.

THEME ONE

CHANGES IN MISSION, CURRICULUM, RESOURCES, AND PEDAGOGY

Hypothesis 1:

V&C has increased the inclusion of undergraduate research during the academic year, including in community colleges, because the emphasis on competencies has legitimized depth versus breadth. (9)

Possible evidence to consider: adoption of Course-Based Undergraduate Research Experiences (CUREs) (e.g., the Small World Initiative, the SEA-PHAGES program, local projects); adoption of research activities by community colleges.

Hypothesis 2:

Departmental/college missions and values have changed as a result of V&C. (8)

Possible evidence to consider: policy, promotion, tenure, and hiring standards; strategic plan language; climate surveys.

Hypothesis 3:

V&C has motivated curriculum reform. (7)

Possible evidence to consider: reform of individual courses; reform of overall curriculum; pedagogy workshops offered; discipline-based education research (DBER) fellows/postdocs.

Hypothesis 4:

Department/college educational practices have changed as a result of V&C. (5)

Possible evidence to consider: learning goals; outcomes; assessment; program improvement.

Hypothesis 5:

Department/college operational practices have changed as a result of V&C. (5)

Possible evidence to consider: base budget; facilities, faculty lines; other resource allocation.

TABLE 2: EFFECTS OF VISION AND CHANGE: HYPOTHESES AND EVIDENCE

Hypothesis 6:
V&C has stimulated the creation of more active learning resources for faculty and students. (3)

Possible evidence to consider: types of resources; resource development opportunities; use of non-traditional teaching methods; participation in RCN-UBE networks; textbook marketing and ancillary materials.

Hypothesis 7:
Disciplinary differences are apparent in the adoption and implementation of *V&C* in courses. (0)

Hypothesis 8**:**
No difference occurs in the effect of *V&C* across types of institutions. (Null)

THEME TWO

IMPACT ON EQUITY, DIVERSITY, AND INCLUSION

Hypothesis 9:
***V&C* has promoted diversity and inclusion of underrepresented groups in biology because it promotes inclusive practices.** (14)

Possible evidence to consider: see Discussion 4, Group A, for an in-depth exploration.

Hypothesis 10:
There is no difference in the effect of *V&C* across types of institutions (two-year vs. four-year, large research R1 vs. liberal arts). (Null)

THEME THREE

IMPACT ON PROMOTION OF NETWORK DEVELOPMENT AND COLLABORATION

Hypothesis 11:
***V&C* has promoted communications networks within the biological sciences by providing a common framework, shared language, and specific goals for undergraduate biology education.** (5)

Possible evidence to consider: communication networks created after *V&C* that discuss undergraduate biology education (e.g., the Partnership for Undergraduate Life Sciences Education (PULSE); Professional Society Alliance for Life Science Education (PSALSE); departmental discussions about curricular issues).

TABLE 2: EFFECTS OF VISION AND CHANGE: HYPOTHESES AND EVIDENCE

Hypothesis 12:

_V&C_ has promoted collaboration and healthy competition between professional societies. (0)

Possible evidence to consider: participation in the Professional Society Alliance for Life Science Education (PSALSE); recent *CBE-Life Science Education* paper on *V&C* efforts[1]; CourseSource efforts to allow each society to see what others have done and learn from one another.

THEME FOUR

IMPACT ON STUDENT ATTITUDES AND LEARNING

Hypothesis 13:

V&C enabled a common lexicon and goals to support transition from two-year to four-year schools. (13)

Possible evidence to consider: alignment of curriculum at two-year and four-year schools; student transfer success.

Hypothesis 14:

Implementation of _V&C_ improves student attitudes toward science and technology by placing science and technology into a relevant context as part of their lives. (8)

Hypothesis 15:

Curricular changes that reflect core competencies positively affect retention in biology programs/courses at community colleges and elsewhere (because _V&C_ increases the use of active learning strategies that engage students, and because it supports a common language that carries over into other courses). (2)

Hypothesis 16:

When _V&C_ is integrated into introductory courses, students are better prepared for upper division courses. (0)

1 Matyas, M.L., Ruedi, E.A., Engen, K., and Chang, A.L. (2017). Life Science Professional Societies Expand Undergraduate Education Efforts. *CBE—Life Sciences Education, 16:*ar5, https://doi.org/10.1187/cbe.16-01-0019

TABLE 2: EFFECTS OF VISION AND CHANGE: HYPOTHESES AND EVIDENCE

THEME FIVE

IMPACT ON FACULTY HIRING, DEVELOPMENT, AND TRAINING

Hypothesis 17:

***V&C* has affected pedagogical training of future faculty.** (3)

Possible evidence to consider: number of training opportunities; participation in training opportunities; positions attained; teacher evaluation; attitude surveys.

Hypothesis 18:

Following *V&C*, education funders provided a greater level of support for faculty development to cultivate pedagogical practices identified in *V&C*. (2)

Possible evidence to consider: content of funded proposals from Sloan, Howard Hughes Medical Institute (HHMI), the National Science Foundation (NSF), and the Department of Education.

Hypothesis 19:

More people have been hired into teaching-intensive and DBER positions since *V&C* came out, and *V&C* principles are valued in hiring and evaluation processes. (2)

Hypothesis 20:

Early career faculty are aware of *V&C* principles, and use them in developing their first courses. (2)

THEME SIX

SCHOLARSHIP OF TEACHING AND LEARNING (SOTL) AND DISCIPLINARY SOCIETY INVOLVEMENT

Hypothesis 21:

***V&C* has enabled professional societies to change their culture to emphasize education.** (5)

Possible evidence to consider: increased opportunity for faculty to present and promote educational reform efforts; increased number of conference presentations on education; increased abstract and poster presentations; increased participation in sessions on education; increased scholarly publications on education topics; common language bridges between two- and four-year faculty, research faculty and instructional faculty; increased *V&C* citations in disciplinary society talks, presentations, posters, and abstracts.

Hypothesis 22:

***V&C* has promoted the scholarship of teaching and learning. (0)**

Possible evidence to consider: publications citing *V&C*; attendance at Science of Teaching and Learning/Discipline-based Education Research conferences; founding of CourseSource and Gordon Research Conference in Undergraduate Biology Education Research (GRC UBER).

DISCUSSION 4:

Brainstorming Evidence

GUIDING QUESTIONS:

- ***What evidence would be credible and convincing to support the emerging hypotheses?***
- ***What data and sources could document an impact? Which stakeholders could provide data and perspectives? How could one access those data?***
- ***What help could each group member personally provide (e.g., contacts with stakeholders, access to certain data, entrée to various professional groups who are stakeholders)?***

Participants convened in small groups to discuss potential evidence that could be gathered and used in regard to seven major areas of potential impact from *Vision & Change.* The variations in the group conversations are reflected in the group reports below. The results of these brainstorming discussions can be used to guide further research examining the impact of *Vision & Change*. The ideas of the participants are provided as bullet points, since they were offered in the context of a fast-paced brainstorming exercise.

"How many people are aware of the report, have read it, and have incorporated* Vision & Change *into their work? What is the effect on students in terms of knowledge and skills gained? And how do we determine the effect?"

GROUP A:
V&C IMPACT ON DIVERSITY, INCLUSION, AND EQUITY

POSSIBLE EVIDENCE:

- The sections in *V&C* pertaining to inclusion and diversity are the least referenced. Overall, parity still does not exist in undergraduate biology education.
- What deliberate actions can be taken to update strategies to focus on learning for all students? The legitimacy around *V&C* can be used to push this challenge more fully into the spotlight. Specifically, the legitimacy of *V&C* allows the community to have hard conversations about equity and intersectionality.

GROUP B:

V&C IMPACT ON INCLUSION OF THE UNDERGRADUATE RESEARCH IN THE CURRICULUM

POSSIBLE EVIDENCE:

- Review funding records of NSF and HHMI to find evidence of support for undergraduate research.
- Review related initiatives, including Small World, Science Education Alliance (SEA) – Phages, Community College Undergraduate Research Initiative (CCURI), Quantitative Undergraduate Biology Education and Synthesis (QUBES), Predictive Analytics Reporting (PAR) Framework, Genome Education Partnership (GEP), Genome Consortium for Active Teaching (GCAT), etc.
- Investigate curricular changes by looking at catalogues, institutional recruiting data, and PULSE data.
- Investigate biotech job preparedness.
- Review Vertically Integrated Projects (VIP) program.

GROUP C:

V&C IMPACT ON TWO-YEAR TO FOUR-YEAR SCHOOL TRANSITION SUCCESS

POSSIBLE EVIDENCE:

- Overall grade point average (GPA) data.
- Grades in common courses (e.g., cell biology).
- Retention in STEM majors; change to other majors.
- Length of time to graduate.
- Number of non-majors who become majors.
- Data from several PULSE rubrics, including Curriculum Alignment rubric.
- Number of students who successfully transfer (articulate).
- Frequency of curriculum mapping and reform in departments.
- Evidence of undergraduate research/course-based university research experiences (CUREs).
- Articulation agreements.
- Frequency of curriculum mapping and reform in departments.
- Evidence of undergraduate research /CUREs.

DATA, SOURCES, AND STAKEHOLDERS:

- Compare institutions that have interacted with PULSE to those that have not had such interaction (more than 60 two- and four-year institutions in the Northwest have interacted with PULSE).
- Access to CUREs at community colleges and investigation into the relationship of these efforts with *V&C.*

- Level of "buy-in" to the principles and ideas of *V&C* among faculty in two- and four-year institutions.
- Examination of what "articulation" means at different institutions and whether *V&C* has informed articulation agreements in the life sciences.
- Notes from meetings about articulation.
- Extent that biology programs are aligning with PULSE curriculum rubrics.
- Review concept inventory scores to assess preparation of students from institutions that have explicitly mapped their programs with *V&C.*
- Examine course syllabi for presence of higher-order outcomes on Bloom's taxonomy and alignment with *V&C.*
- Evidence from student posters from research symposia of alignment with *V&C.*
- Interviews with, and surveys of, students about their familiarity with *V&C* or its principles, including their views on competencies and content.
- Interviews about the impact of *V&C* on the implementation of CUREs or curriculum reform.

WAYS TO ACCESS RELEVANT DATA:

- PULSE Fellows have access to some relevant data.
- Collect concept inventory data.

GROUP D:
V&C IMPACT ON ACTIVE LEARNING RESOURCES FOR STUDENTS AND FACULTY

POSSIBLE EVIDENCE:

- Variety of types of active learning resources produced.
- Measurements of active learning in practice (possibly use a citizen science approach to get a baseline); active learning baseline measurement.
- Number of publications.
- Number of faculty development opportunities (e.g., scientific society workshops, summer institutes, Project Kaleidoscope – PKAL).
- Number of people involved in professional development related to active learning.
- Number of places to publish (e.g., scientific society meetings, CourseSource; *Journal of Microbiology and Biology Education* [JMBE], *CBE—Life Science Education*, etc.).
- Number of grants that support the development of active learning resources (including NSF's Research Coordination Networks in Undergraduate Biology Education).
- Textbook changes (e.g., marketing, ancillary materials).
- Use of non-traditional teaching methods and technologies.
- Professional society activities related to active learning.
- Places to publish active learning materials.

STAKEHOLDERS:

- Scientific societies.
- Funders.
- Publishers, journal editorial boards.
- Communities of practice for instructors.
- Centers for teaching and learning, and teaching academies.
- Measurements of amount of active learning in biology college classrooms (e.g., Classroom Observation Protocol for Undergraduate STEM [COPUS], Decibel Analysis for Research in Teaching [DART] index, etc.).

WAYS TO ACCESS RELEVANT DATA:

- Survey faculty to ask whether they are doing active learning and, if so, what kinds.

GROUP E:
V&C IMPACT ON STUDENT ATTITUDES TOWARD SCIENCE AND TECHNOLOGY

POSSIBLE EVIDENCE:

- Enrollment and retention data.
- Focus on markers of attitude rather than asking about the attitude itself. Markers could include:
  - Retention in sciences.
  - Measurements of *why* students leave science (reasons may change if *V&C* is effective).

WAYS TO ACCESS RELEVANT DATA:

- Use a survey to investigate student attitudes.
  - Use pre-course/mid-course/post-course surveys to see changes in attitudes toward science.
  - Compare sections using *V&C* versus a section that has not adopted *V&C.*
  - Analyze shifts in attitudes toward science, not in the teaching methodology.
  - Use surveys that have been used prior to *V&C* to see whether they show any changes since adopting *V&C.*
  - Measure positive/negative attitudes about science.
- Colorado Attitudes Survey (CLASS), which is peer-reviewed and published.
- Society for the Advancement of Biology Education Research (SABER) list.
- Work with professional societies.

GROUP F:

V&C IMPACT ON COLLEGE/DEPARTMENT MISSIONS AND VALUES

POSSIBLE EVIDENCE:

- Evidence about mission statements, hiring policies, tenure and promotion guidelines, teaching strategies, teaching practices, and the extent to which change is occurring. Such evidence could be gathered in multiple ways:
  - Interviews with faculty, deans, and department chairs to examine how departments have changed in relation to *V&C.*
  - Review of departmental documents showing the impact of *V&C.*
  - Snapshots of websites where mission statements have been archived.
  - Use of COPUS for classroom observations.
  - Climate surveys to explore extent of awareness of *V&C.*
  - PULSE rubrics.
  - Matched cohort analyses (institutional case studies). Consider early *V&C* adopters and more recent *V&C* adopters, as well as matched institutions who have not requested *V&C* help.
- Evidence about changes in operational practices:
  - Changes in amount and percentages of related budget allocations.
  - Facilities (new learning spaces).
  - Number of faculty lines for DBER and instructional faculty.
  - Start-up packages for DBER faculty versus for other research faculty.
  - Faculty development support for faculty development aligned with *V&C.*
  - Requirement of a "teaching talk" in hiring procedures.
  - Integration of core concepts in *V&C* with promotion and tenure standards.
- Evidence of faculty use of *V&C* in teaching:
  - Use of case studies, discussion, anecdotes.
  - Use of rubrics aligned with *V&C* for evaluating teaching.

STAKEHOLDERS:

- PULSE Fellows, who have much data and the potential for partnership.
- Faculty, deans, and other administrators at institutions.
- SABER, GRC-UBER, and Network of STEM Education Centers (NSEC).

WAYS TO ACCESS RELEVANT DATA:

- Web searches of old and new mission statements.
- Connect with PULSE recognition and ambassador groups that have rubric data.
- Web surveys and/or specific interviews with departments.

GROUP G:

V&C AND IMPACT ON CURRICULAR REFORM AND EDUCATIONAL PRACTICES

POSSIBLE EVIDENCE:

- Collect data from accreditors (check data down to the level of departments; review pre- and post-*V&C*; review outcomes over time).
- Conduct a meta-analysis of the literature about reforming introductory courses.
- Analyze abstracts of programs that have been funded (NSF, HHMI, Sloan, Gates, Lumina) to see whether projects that align with *V&C* are being funded.
- Analyze GRE data before and after *V&C.*
- Compare ETS Major Field Test data before and after *V&C.*

STAKEHOLDERS:

- Work with institutional organizations and networks, such as APLU, AAU, American Association of Community Colleges (AACC), AAC&U, the Council of Independent Colleges (CIC), and the Association Supporting Computer Users in Education (ASCUE).
- Work with diverse institutions (e.g., Historically Black Colleges and Universities (HBCUs), Hispanic-Serving Institutions (HSIs), tribal colleges).
- Investigate Richard Arum's project on undergraduate learning outcomes (see: Arum, R., Roska, J., and Cook, A. (eds). (2016). *Improving Quality in American Higher Education: Learning Outcomes and Assessments for the 21st Century*. San Francisco: Jossey-Bass).
- Connect with NSF about the National Survey of Post-Secondary Faculty (NSOPF) and encourage further administration of this survey to provide widespread data about faculty teaching practices.
- Connect with institutions involved in RCN-UBE projects, and possibly those with NSF Widening Implementation & Demonstration of Evidence Based Reforms (WIDER) or NSF Innovative Technology Experiences for Students and Teachers (ITEST) grants.

FINAL COMMENTS:

The meeting concluded with strong interest expressed among participants in finding ways to examine more deeply the possible areas of impact of *Vision & Change*. Participants hoped that the hypotheses and suggested lines of evidence will help guide further research examining the impact of *Vision & Change*.

Anne E. Austin

CHARGE:

LETTER FROM SHIRLEY MALCOM

Discussions around what became *Vision & Change* began back more than a decade ago. At the time that the community undertook this journey, the focus was very much on why change was needed—the explosion of knowledge within the biological sciences, the disconnect between the way biology was taught and the way it was done, and a better understanding of how people learned. The community knew that change was needed, but, what would that change look like?

I went back "home" a few weeks ago...not to Birmingham where I was born and raised, but to my academic home. I was invited to give the commencement address to the more than 600 graduates of the University of Washington Department of Biology (Class of 2018). The visit was especially meaningful to me, coming 51 years after my own graduation and being introduced by my mentor, one of the key people responsible for my being where I am today.

Most of the members of this class began their studies in the department after 2011, that is, post-*Vision & Change.* They benefited from the conversations the biology community had been having for the previous decades about the nature of biology education. They had a faculty community committed to active learning, and discipline-based education researchers who were considering how the design of courses, a focus on concepts, mindful assessment, attention to competencies and community building helped ensure how all students might be successful. Not only has this department attended to its own students, but also it has had faculty, graduate students and post-doctoral scholars who have contributed to the national discussion about improving undergraduate biology education and increasing the diversity of those so educated.

The contours of the department's efforts emerged as the graduation program went on, as the lead for undergraduate biology asked different groups of graduating seniors to stand: peer tutors; those involved in community work; those in biology honors; students who had been involved in research. As much as I love stories, the data that appeared in human form as successive groups rose to claim their places were compelling, and revealed much about the shape of the department. Most surprising and impressive to me was when **most** of the class rose when asked if they had participated in research. UW biology is, after all, *BIG* biology, highly intensive research biology, huge intro classes biology. That level of research participation? That was a data point I did not expect.

"If we know that particular forms of instruction or course design produce better outcomes for all students, how do we justify not using them?"

I do not know what *Vision & Change* caused or enabled. I'm not sure whether or how *V&C* supported the reflection by faculty that has led to the shape of this program. In all likelihood, it offered a platform and authority to those departmental leaders who believed this was the way to go. Should I start wandering from one bio department commencement to another across the country, where the same questions are asked of its graduates, I would probably find other programs like this one or perhaps even better than this one. But whatever is happening inside this department seems deeply rooted among the faculty.

So, we return to the observation that was offered in the workshop: we can see points of light, but is there deep penetration into the core of the faculty? How do you get cultural change and sustain it? Certainly, it takes leadership, and it takes time. And perhaps it also takes circumstances. Biology at UW is a relatively new department, formed from the merger of botany, zoology (where I was based), and undergraduate biology education. Perhaps the culture came along with all the other elements attendant to a merger—lots of conversation, lots of listening, introspection, self-assessment.

It certainly takes a willingness to look at one's own outcomes: demographically, who comes to the program; who is retained in the program; who is successful in the program; what experiences do students have; can they find community; what do they go on to do; and much more.

And certainly, once these values are in place, you can "hire for them"; given two candidates who can both bring interesting research into the department, you can choose the person who is also "deeply rooted" in the idea and ideals of *Vision & Change*. And each time a department goes through the hiring process it has an opportunity to revisit, reflect on and reaffirm its values related to undergraduate education. And the word will go out to graduate students and post-docs that this understanding of undergraduate biology education is valued by departments (or at least by this department) that are hiring new faculty, and...and...and.... Such is the nature of systemic change; such is the nature of "movements": reflective and self-reinforcing.

"What are our community responsibilities to the next generation of learners and how can we fulfill these?"

As noted by participants in the workshop, *Vision & Change* as a movement allowed those individuals committed to reform or to transformation to "**find** each other." After coming together, they were able to **refine** their vision for what they wanted as outcomes, in terms of conceptual understanding as well as in terms of developing competencies. As a community, they could **define** the goals they wished to advance and as leaders, **align** local resources to support these. Thus, they could promote the top-down, bottom-up strategies needed for a movement.

The role of funders was pivotal to incentivizing transformation/dis-incentivizing the status quo. Donors and community leaders can help **legitimize** change, giving permission to move toward a futures focus. This movement began from a realization that changes in biology itself as well as in the science of learning were not reflected in

the way we educate in biology. Knowing better obligated us to **do** better. Thus, emerges a powerful social justice rationale for transformation. If we know that particular forms of instruction or course design produce better outcomes for all students, how do we justify not using them?

The moral imperative of a movement is not something that has emerged in our discussions, but it is implicit in our work. What are our community responsibilities to the next generation of learners, and how can we fulfill these?

I know what I observed from my vantage point on the stage at commencement. But what happened in the department over the preceding years to produce that picture, and what role, if any, did *Vision & Change* play in the story? How can the lessons learned from this movement inform the work of other biology departments and other fields? Those are the next challenges to be faced and the next chapters to be written.

Shirley M. Malcom

Shirley M. Malcom, Ph.D.

CASE STUDY:

Impact of *Vision & Change* on UW Biology

"I do not know what Vision & Change *caused or enabled."*
~ Shirley Malcom

Alison Crowe, Ph.D., principal lecturer for the Department of Biology at the University of Washington, recounts the change efforts in her department.

Vision & Change was published at a time when our department was already engaged in conversations about how and what we should be teaching our students. Individual faculty had begun practicing active-learning strategies in the classroom and developing structured activities to help students learn challenging concepts.

An important shift in our department came with the recognition that we needed to gather data to know if the changes we were making were helping students learn. This led us to initiate research projects aimed both at measuring the effectiveness of different pedagogical approaches and better understanding how social interactions impact learning.[1] Having a call to action that laid out a collective vision of what biology departments nationally wanted undergraduate majors to know and be able to do by the time they graduate provided us with the necessary framework to guide these efforts.

One question we wanted to ask was how well were we doing at teaching the core concepts outlined by *Vision & Change*. In order to do this, however, we realized we first needed to better define what we meant by "understanding" each of the core concepts at the cellular-, tissue-, and ecosystem-level. For example, what did it mean to the ecologists in our department for a student to understand "information flow"? This initiated a series of small-group faculty conversations around these questions.

The results of these conversations, and broader interest from the biology community, led us to develop the BioCore Guide,[2] a nationally validated set of key principles and knowledge statements underlying each core concept. Having the BioCore Guide has helped us re-focus our conversations about which specific topics to include in a syllabus into a broader discussion of the major concepts we want our students to know. To help answer our original question of whether our students are learning these key concepts, we have taken part in a multi-institution effort to develop program-level biology assessments (BioMAPS) aligned with the BioCore Guide. We can now use these assessments as one measure of how successful our department is at teaching the core concepts.

1 One important product that came out of this shift was a meta-analysis illustrating the benefits of active learning over traditional lecturing: Freeman, S., Eddy S.L., McDonough M., Smith M.K., Okoroafor N., Jordt, H. and Wenderoth, M.P. (2014). Active learning boosts performance in STEM courses. *Proceedings of the National Academy of Sciences, 111* (23), 8410-8415. doi: 10.1073/pnas.1319030111.

2 Brownell, S. E., Freeman, S., Wenderoth, M. P., and Crowe, A. J. (2014). BioCore Guide: A Tool for Interpreting the Core Concepts of Vision and Change for Biology Majors. *CBE—Life Sciences Education, 13 (*2), 200–211. doi: 10.1187/cbe.13-12-0233.

Over the past few years, we have initiated a similar grassroots approach to better define what specific skills we want our majors to have by the time they graduate. The momentum for this new department-wide effort has been driven by sustained faculty and staff participation in PULSE workshops (see pulsecommunity.org). What began as an effort to reshape our own curriculum with *Vision & Change* as a framework has led to the development of tools that we hope others can use as starting points to initiate similar conversations in their own departments.

Another tenet of *Vision & Change* is that students learn better by doing science. To engage more students in the practice of research, we have made a concerted effort over the past eight years to develop new course-based undergraduate research experiences (CUREs) for juniors and seniors. This has had the added benefit of connecting undergraduates with research faculty in a small laboratory environment and helping newly hired faculty integrate their teaching and research efforts. The majority of our majors currently enroll in a CURE or do independent research. HHMI funding has also led to development of an introductory-level CURE, which we are currently scaling up for implementation in our introductory biology series to provide early exposure to research for all students.

Throughout this curriculum revision process we have benefited directly from 1) commitment by departmental leadership to invest in evidence-based approaches and create a culture that values teaching; 2) internal and external funding of biology education research projects; and, perhaps most important, 3) a community of faculty, graduate students, and staff excited to engage in conversations about teaching.

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

This report is on the website at www.visionandchange.org.

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