



Supporting Online Material for

Changing the Culture of Science Education at Research Universities

W. A. Anderson, U. Banerjee, C. L. Drennan, S. C. R. Elgin, I. R. Epstein, J. Handelsman, G. F. Hatfull, R. Losick,* D. K. O'Dowd,* B. M. Olivera, S. A. Strobel, G. C. Walker, I. M. Warner

*To whom correspondence should be addressed. E-mail: losick@mcb.harvard.edu;
dkodowd@uci.edu

Published 14 January 2011, *Science* **331** 152 (2010)
DOI: 10.1126/science.1198280

This PDF file includes

References

Science Supporting Online Material

POLICY FORUM: **Changing the Culture of Science Education at Research Universities**

W. A. Anderson,¹ U. Banerjee,² C. L. Drennan,³ S. C. R. Elgin,⁴ I. R. Epstein,⁵ J. Handelsman,⁶
G. F. Hatfull,⁷ R. Losick,^{8*} D. K. O'Dowd,^{9*} B. M. Olivera,¹⁰ S. A. Strobel,⁶ G. C. Walker,³ I. M. Warner¹¹

¹Howard University, Washington, DC 20059, USA. ²University of California, Los Angeles, Los Angeles, CA 90095, USA. ³Massachusetts Institute of Technology, Cambridge, MA 02139, USA. ⁴Washington University, St. Louis, MO 63130, USA. ⁵Brandeis University, Waltham, MA 02453, USA. ⁶Yale University, New Haven, CT 06520, USA. ⁷University of Pittsburgh, Pittsburgh, PA 15260, USA. ⁸Harvard University, Cambridge, MA 02138, USA. ⁹University of California, Irvine, Irvine, CA 92697, USA. ¹⁰University of Utah, Salt Lake City, UT 84112, USA. ¹¹Louisiana State University, Baton Rouge, LA 70803, USA.

*To whom correspondence should be addressed. E-mail: losick@mcb.harvard.edu or dkodowd@uci.edu

References suggested by R.R. Hake on 11 January 2011. All URL's accessed on 11 January 2011; some URL's shortened by <<http://bit.ly/>>.

I. Undergraduate Education Reform

Barr, R.B. & J. Tagg. 1995. "From Teaching to Learning: A New Paradigm for Undergraduate Education," *Change* **27**(6); 13-25, November/December; online as a 111kB pdf at <<http://bit.ly/8XGJPC>>. Reprinted in Dezure (2000), pp. 198-200.

Bok, D. 2005. *Our Underachieving Colleges: A Candid Look at How Much Students Learn and Why They Should Be Learning More*. Princeton University Press. Publisher's information (including the preface and Chapter 1) is online at <<http://bit.ly/9eow38>>.

Bransford, J.D., A. L. Brown, & R.R. Cocking, eds. 2000. *How People Learn: Brain, Mind, Experience, and School: Expanded Edition*, National Academy Press, online at <<http://bit.ly/fVCQ6M>>: "originally released in hardcover in the Spring of 1999, has been newly expanded to show how the theories and insights from the original book can translate into actions and practice, now making a real connection between classroom activities and learning behavior. This paperback edition includes far-reaching suggestions for research that could increase the impact that classroom teaching has on actual learning."

Bush, S.D., N.J. Pelaez, J.A. Rudd, M.T. Stevens, K.D. Tanner, & K.S. Williams. 2008. "Science Faculty with Education Specialties," *Science* **322**: 1795-1796; online at <<http://bit.ly/d8brEd>>.

Coil, D., M.P. Wenderoth, M. Cunningham, and C. Dirks. 2010. "Teaching the Process of Science: Faculty Perceptions and an Effective Methodology," *CBE Life Sci Edu* **9**(4): 524-535; online at <<http://bit.ly/e5XlkJ>>.

Dancy, M. & C. Henderson. 2010. "Pedagogical practices and instructional change of physics faculty." *Am. J. Phys.* **78**(10): 1056-1063; online as a 426 kB pdf at <<http://bit.ly/9b4rX1>>. The authors wrote: ". . . self-reports of actual classroom practices indicate that the availability of . . . [physics education research curricula and pedagogies]. . . has not led to fundamental changes in instruction. . . [suggesting]. . . a need for research-based dissemination that accounts for the complexity of instructional change." In this regard see Fairweather (2008).

DeHaan, R.L. 2005. "The Impending Revolution in Undergraduate Science Education," *Journal of Science Education and Technology* **14**(2): 253-269; abstract online at <<http://bit.ly/cqIK1w>>.

DeHaan, R.L. 2009. "Teaching Creativity and Inventive Problem Solving in Science," *CBE Life Sci Educ* **8**(3): 172-181; online at <<http://bit.ly/btx32v>>.

Dezure, D. 2000. *Learning from Change: Landmarks in Teaching and Learning in Higher Education from Change 1969-1999*, foreword by Theodore J. Marchese. Stylus, publisher's information at <<http://bit.ly/fQHoim>>. Amazon.com information at <<http://amzn.to/hLX4s8>>. An expurgated Google book preview is online at <<http://bit.ly/ezgdPH>>.

Donovan, M.S. & J.D. Bransford, eds. 2005. *How Students Learn History, Mathematics, And Science In The Classroom*. National Academies Press; online at <<http://bit.ly/baJyu7>>.

Duderstadt, J.J. 2000. *A University for the 21st Century*. Univ. of Michigan Press (2000); for a description see <<http://bit.ly/cvJ1yI>>.

Fairweather, J. 2008. "Linking Evidence and Promising Practices in Science, Technology, Engineering, and Mathematics (STEM) Undergraduate Education: A Status Report for The National Academies National Research Council Board of Science Education," online at <<http://bit.ly/ePTL0W>>. According to Labov et al. (2009) Fairweather "was asked to review and synthesize all of the additional articles submitted for the October workshop. . . .[[see National Academies (2008).]" Fairweather wrote: "NSF- and association-funded reforms at the classroom level, however well intentioned, have not led to the hoped for magnitude of change in student learning, retention in the major, and the like *in spite of empirical evidence of effectiveness*. . . . [[*italics in the original*]]. . . Among the most important elements of a successful change strategy to promote the improvement of undergraduate STEM education. . . .[[is recognizing]]. . . that more effort needs to be expended on strategies to promote the adoption and implementation of STEM reforms rather than on assessing the outcomes of these reforms. Additional research can be useful but the problem in STEM education lies less in not knowing what works and more in getting people to use proven techniques." The difficulty of "getting people to use proven techniques" has been emphasized by Dancy & Henderson (2010).

Hacker, A. & C. Dreifus. 2010. *Higher Education?: How Colleges Are Wasting Our Money and Failing Our Kids – and What We Can Do About It*. Holt/Times Books. Amazon.com information at <<http://amzn.to/bunggt>>. See also the Hacker/Dreifus blog <<http://bit.ly/gJp4Pg>>.

Hake, R.R. 2002. "Lessons from the Physics Education Reform Effort," *Ecology and Society* **2**: 28; online at <<http://bit.ly/aL87VT>>.

Hake, R.R. 2005. "The Physics Education Reform Effort: A Possible Model for Higher Education?" online as a 100 kB pdf at <<http://bit.ly/9aicfh>>; a slightly edited version of the article that was: (a) published in the *National Teaching and Learning Forum* (NTLF) **15**(1), December 2005, online to subscribers at <<http://bit.ly/bvm8Ye>> (If your institution doesn't subscribe to NTLF, it *should*); (b) disseminated in *Tomorrow's Professor* Msg. #698 on 14 Feb 2006 archived at <<http://bit.ly/d09Y8r>> - type the message number into the slot at the top of the page.

Hake, R.R. 2007a. "Six Lessons From the Physics Education Reform Effort," *Latin American Journal of Physics Education* **1**(1), September; online (with AIP style numbered references) as a 124 kB pdf at <<http://bit.ly/bjvDOb>> (124 kB). Also available with APA style references as a 684 kB pdf at <<http://bit.ly/96FWmE>> (684 kB).

Hake, R.R. 2007b. "Can Scientific Research Enhance the Art of Teaching?" invited talk, AAPT Greensboro meeting, 31 July, online as a 1.2 MB pdf at <<http://bit.ly/a7xJxR>>. See esp. Sect. V. "University Leaders Bemoan the Inertia of Higher Education: Why Is It So Slow To Recognize the Value of Interactive Engagement Methods in Promoting Higher-Level Learning?"

Handelsman, J., D. Ebert-May, R. Beichner, P. Bruns, A. Chang, R. DeHaan, J. Gentile, S. Lauffer, J. Stewart, S.M. Tilghman, & W.B. Wood. 2004. "Scientific Teaching," *Science* **304** (23): 521-522, April; online as a 100 kB pdf at <<http://bit.ly/aQbF8G>>. See also the supporting material online as a 344 kB pdf at <<http://bit.ly/eOCJmo>> [URL's are specified for some, but (unfortunately) not all, online materials].

Handelsman, J., S. Miller, & C. Pfund, 2007. *Scientific Teaching*, Freeman. Amazon.com information at <<http://amzn.to/aKssNI>>.

Kennedy, D. 1999. *Academic Duty*. Harvard University Press, publisher's information at <<http://bit.ly/edBogg>>. Amazon.com information at <<http://amzn.to/hbeAsp>>, note the "Look Inside" feature. An expurgated Google book preview is online at <<http://bit.ly/hmuC5R>>.

Labov, J.B., S.R. Singer, M.D. George, H.A. Schweingruber, & M.L. Hilton. 2009. "Effective Practices in Undergraduate STEM Education Part 1: Examining the Evidence," *CBE Life Sci Educ* **8**(3): 157-161; online at <<http://bit.ly/cRc0JC>>. This is a discussion of the "Workshop on Linking Evidence and Promising Practices in STEM Undergraduate Education" [National Academies (2008)].

Langenberg, D.N. 2004. "This Requires a Fundamental Culture Change," *Science* **304** (23); online at <<http://bit.ly/dS3GST>>, comment on Handelsman et al. (2004). Langenberg, former Chancellor of the University of Maryland System, wrote: "[I] take issue with [the first sentence of the second paragraph of Handelsman et al. (2004) that] 'it may seem surprising that change has not progressed rapidly nor been driven by the research universities as a collective force.' It is not at all surprising. Cultural change is a slow process requiring decades, even centuries. Confronted by such a challenge, 'research universities as a collective force' are essentially impotent. Hope lies in the fact stated in the paragraph, 'reform has been initiated by a few pioneers.' Such pioneers, some in research universities and some not, are growing in number and influence. We should look to them for leadership in converting their faculty colleagues to the cause. Individual institutions can encourage and support them, but real cultural change can only be driven from the faculty level."

McDaniel, M.A. & A.A. Callender. 2008. "Cognition, memory, and education" in J.H. Byrne, ed., Volume 2: *Cognitive Psychology of Memory*, pp. 819-843, of the four volume set *Learning and Memory - A Comprehensive Reference*. Oxford: Elsevier; an abstract is online at <<http://bit.ly/gALeI5>>. A pre-publication version is online as a 1.3 MB pdf at <<http://bit.ly/e0PW2C>> which begins "Our focus in this chapter rests on the observation that much learning in the classroom consists of the acquisition of factual information." But see "Just the Facts? Introductory Undergraduate Biology Courses Focus on Low-Level Cognitive Skills" [Momsen et al. (2010)].

Michael, J. 2006. "Where's the evidence that active learning works?" *Advances in Physiology Education* **30**: 159-167, online at <<http://bit.ly/9x4I7g>>, a masterful review by a medical education researcher/developer.

Millis, B. ed. 2010. *Cooperative Learning in Higher Education: Across the Disciplines, Across the Academy (New Pedagogies and Practices for Teaching in Higher Education)*, foreword by James Rhem. Stylus. Amazon.com information at <<http://amzn.to/b1Ysa1>>. Note the searchable "Look Inside" feature.

National Academies. 2005. *Workshop on Education Research Positions in STEM Disciplinary Departments: Number 2 in the Series of CFE Symposia on Growing Human Capital in STEM Higher Education*," online at <<http://bit.ly/dcVKNb>>.

National Academies. 2008. "Evidence on Promising Practices in Undergraduate Science, Technology, Engineering, and Mathematics (STEM) Education: Workshop on Linking Evidence and Promising Practices in STEM Undergraduate Education" online at <<http://bit.ly/fAhNpA>>: Meeting 1 of 30 June, online at <<http://bit.ly/ciNwjQ>>; Meeting 2 of 13-14 October containing commissioned papers online at <<http://bit.ly/ceg1Bx>>. See also the commentary on these workshops by Labov et al. (2009) and by Fairweather (2008), who (according to Labov et al.) "was asked to review and synthesize all of the additional articles submitted for the October workshop."

Nelson, C. 2009. "Dysfunctional Illusions of Rigor: Lessons from the Scholarship of Teaching and Learning," Chapter 10 in Nilson & Miller (2009); also in the *Tomorrow's Professor* messages 1058 and 1059 of 12 and 16 November 2010, archived at <<http://bit.ly/d09Y8r>> - type the message numbers into the slot at the top of the page.

Nilson, L.B. and J.E. Miller, eds. 2009. *To Improve the Academy: Resources for Faculty, Instructional, and Organizational Development, Volume 28*, Jossey-Bass. Barnes & Noble information at <<http://bit.ly/9soRDk>>, note the searchable "See inside" feature.

Rimer, S. 2009. "At M.I.T., Large Lectures Are Going the Way of the Blackboard," *New York Times*, 12 January; online at <<http://nyti.ms/awEWKY>>.

Stokstad, E. 2001. "Reintroducing the Intro Course," *Science* 293: 1608-1610, 31 August; online at <<http://bit.ly/a018BM>>. Stokstad wrote: "Physicists are out in front in measuring how well students learn the basics, as science educators incorporate hands-on activities in hopes of making the introductory course a beginning rather than a finale."

Wood, W.B., & J.M. Gentile. 2003. "Teaching in a research context," *Science* **302**: 1510; 28 November; a summary is online at <<http://bit.ly/hvJTiQ>>.

Wieman, C. 2007. "Why Not Try a Scientific Approach to Science Education?" *Change Magazine*, September/October; online as a 804 kB pdf at <<http://bit.ly/anTMfF>>.

Wehlburg., C.M., ed. 2010. *New Directions in Teaching and Learning, Vol. 2010, No. 123*; Special Issue: "Landmark Issues in Teaching and Learning: A Look Back at New Directions for Teaching and Learning." Jossey-Bass, publisher's information at <<http://bit.ly/gdecLz>> - includes authors and titles of articles. Amazon.com information at <<http://amzn.to/eclUr4>>. A review by James Rhem in *National Teaching and Learning Forum* **19**(6) is online to subscribers at <<http://bit.ly/hVweNX>> (If your institution doesn't subscribe to NTLF, it *should*).

II. Biology Education Reform

AAAS. 2009. American Association For The Advancement Of Science, "Vision And Change In Undergraduate Biology Education: A Call to Action," online at <<http://visionandchange.org/>>.

Allen, D. & K. Tanner. 2007. "Putting the Horse Back in Front of the Cart: Using Visions and Decisions about High-Quality Learning Experiences to Drive Course Design," *CBE Life Sci. Educ.* **6**(2): 85–89; online at <<http://bit.ly/d7h9Uw>>.

Anderson, D.L., K.M. Fisher, G.J. Norman. 2002. "Development and evaluation of the conceptual inventory of natural selection," *Journal of Research in Science Teaching* **39**(10): 952-978; online as an 848 kB pdf at <<http://bit.ly/a3naJx>>.

Armbruster, P., M. Patel, E. Johnson, & M. Weiss. 2009. "Active Learning and Student-centered Pedagogy Improve Student Attitudes and Performance in Introductory Biology," *CBE—Life Sci Educ* **8**(3): 203–213; online at <<http://bit.ly/9CJaV6>>.

Cech, T.R. 2003. Editorial: "Rebalancing Teaching and Research." *Science* **299**(5604): 165; online at <<http://bit.ly/gacZE2>>.

Dancy, M.H. & R.J. Beichner. 2002. "But Are They Learning? Getting Started in Classroom Evaluation," *Cell Biol Educ* **1**(3): 87-94; online at <<http://bit.ly/dukFuA>>.

D'Avanzo, C. 2008. "Biology concept inventories: overview, status, and next steps," *Bioscience* **58**:1079-1085; an abstract is online at <<http://bit.ly/bklB8X>>.

Ebert-May, D. & J. Hodder. 2008. *Pathways to Scientific Teaching*. Sinauer Associates. Amazon.com information at <<http://amzn.to/akFzgP>>.

Freeman, S. E. O'Connor, J.W. Parks, M. Cunningham, D. Hurley, D. Haak, C. Dirks, & M.P. Wenderoth. 2007. "Prescribed Active Learning Increases Performance in Introductory Biology," *CBE Life Sci Educ* **6**(2): 132-139; online at <<http://bit.ly/cDknzM>>.

HHMI Website <<http://www.hhmi.org/>>, see especially “For Educators” at <<http://bit.ly/blyGtN>>.

HHMI News. 2010a. “HHMI Professors,” 20 May; online at <<http://bit.ly/alXrgy>>.

HHMI News. 2010b. “Awards \$79 Million for Science Education to Research Universities, Top Scientists,” online at <<http://bit.ly/cJcs9t>>.

Jungck, J.R., H.D. Gaff, A.P. Fagen, & J.B. Labov. 2010. “Beyond *BIO2010*: Celebration and Opportunities” at the Intersection of Mathematics and Biology,” *CBE—Life Sci Educ* **9**(3): 143–147; online at <<http://bit.ly/aTQuWz>>.

Klymkowsky, M.W., K. Garvin-Doxas, & M. Zeilik. 2003. “Bioliteracy and Teaching Efficiency: What Biologists Can Learn from Physicists,” *Cell Biology Education* **2**: 155-161; online at <<http://bit.ly/9A1Arx>>.

Klymkowsky, M.W. 2010a. “Conceptual Assessment in Biology Conferences” online at <<http://bioliteracy.colorado.edu/>>. Click on "Biology Concept Assessment" in the left-hand column.

Klymkowsky, M.W. 2010b. “Biology Concept Lists” online at <<http://bioliteracy.colorado.edu/>>, click on "Concept Lists" in the left-hand column.

Klymkowsky, M.W. 2010c. “Bioliteracy.net,” online at <<http://bioliteracy.colorado.edu/>>: “Our goal is to generate, test and distribute the tools to determine whether students are learning what teachers think they are teaching. We assume that accurate and timely assessment of student knowledge will pressure the educational world toward more effective teaching. WHY? (a) Because basic understanding of the biological sciences impacts our lives in more and more dramatic ways every year; (b) A wide range of important personal, social, economic and political decisions depend upon an accurate understanding of basic biology and the means by which science generates, tests and extends our knowledge.” See especially the Wikipedia entry "Concept Inventory" at <http://en.wikipedia.org/wiki/Concept_inventory>.

Klymkowsky, M.W. 2010d. “Thinking about the Conceptual Foundations of the Biological Sciences,” *CBE Life Sci Educ* **9**(4): 405–407; online at <<http://bit.ly/dOWk0p>>.

McDaniel, C., B. Lister, M. Hanna, & H. Roy. 2007. “Increased Learning Observed in Redesigned Introductory Biology Course that Employed Web-enhanced, Interactive Pedagogy,” *CBE Life Sci Educ* **6**(3), 243-249; online at <<http://bit.ly/9vPhqb>>.

Milton, J.G., A.E. Radunskaya, A.H. Lee, L.G. de Pillis, and D.F. Bartlett. 2010. “Team research at the biology-mathematics interface: Project management perspectives,” *CBE Life Sci Educ* **9**(3): 316-322; online at <<http://bit.ly/eJqchg>>.

Momsen, J.L., T.M. Long, S.A. Wyse, and D. Ebert-May. 2010. “Just the Facts? Introductory Undergraduate Biology Courses Focus on Low-Level Cognitive Skills,” *CBE—Life Sci Educ* **9**(4): 435–440; online at <<http://bit.ly/fPWOQ0>>.

Nelson, C. 2010. “Want Brighter, Harder Working Students? Change Pedagogies! Some Examples, Mainly from Biology.” Chapter 8 in Millis (2010) – see under Section I above. Nelson has provided a URL to a late pre/publication version in a POD post at <<http://bit.ly/aRunlP>> - click on “10_Want Brighter in Millis p119-140 Proof.pdf” (360 kB) in the heading “Parts/Attachments.”

NRC. 2003a. *BIO2010: Transforming Undergraduate Education for Future Research Biologists*. National Academies Press; online at <<http://bit.ly/boStbC>>.

NRC. 2003b. *Evaluating and Improving Undergraduate Teaching in Science, Technology, Engineering, and Mathematics*. National Academies Press; online at <<http://bit.ly/aWF3cD>>.

NRC. 2009. *A New Biology for the 21st Century: Ensuring the United States Leads the Coming Biology Revolution*, National Academies Press; online at <<http://bit.ly/8Y65s3>>.

Pfund, C., S. Miller, K. Brenner, P. Bruns, A. Chang, D. Ebert-May, A.P. Fagen, J. Gentile, S. Gossens, I.M. Khan, J.B. Labov, C.M. Pribbenow, M. Susman, L. Tong, R. Wright, R.T. Yuan, Wood, W.B. & J. Handelsman. 2009. “Summer Institute to Improve University Science Teaching,” *Science* **324**: 470-471; abstract online at <<http://bit.ly/aUQAyN>>.

Preszler, R.W. 2009. “Replacing Lecture with Peer-led Workshops Improves Student Learning,” *CBE—Life Sci Educ* **8**(3): 182–192; online at <<http://bit.ly/b3ua2p>>.

Redish, E.F. & D. Hammer. 2009. “Reinventing College Physics for Biologists: Explicating an Epistemological Curriculum,” *Am. J. Phys.* **77**(7): 629-642; online as a 246 kB pdf at <<http://bit.ly/hGcUKH>>.

Roy, H. 2001. “Use of Web-based Testing of Students as Method for Evaluating Courses.” *Bioscene* **27**(3): 3-7; online at <<http://acube.org/bioscene/>>.

Roy, H. 2003. “Studio vs Interactive Lecture Demonstration – Effects on Student Learning,” *Bioscene* **29**(1): 3-6; online at <<http://acube.org/bioscene/>>.

Smith, J.I. & K. Tanner. 2010. “The Problem of Revealing How Students Think: Concept Inventories and Beyond,” *CBE Life Sci Educ* **9**(1): 1-5; online at <<http://bit.ly/dzTA6Z>>.

Smith, M.K., W.B. Wood, & J.K. Knight. 2008. “The genetics concept assessment: a new concept inventory for gauging student understanding of genetics,” *CBE Life Sci. Educ.* **7**(4): 422– 430; online at <<http://bit.ly/dDssbU>>.

Steen, L.A., ed. 2005. *Math & Bio 2010: Linking Undergraduate Disciplines*, The Mathematical Association of American, publisher's information at <<http://bit.ly/gZxLT8>>. Amazon.com information at <<http://amzn.to/eOS92P>>, note the searchable "Look Inside" feature. A review by Judy Holdener is online at <<http://bit.ly/fhJ1aj>>.

Sundberg, M.D. 2002. "Assessing Student Learning." *Cell Biology Education* **1**(1): 11-15; online at <<http://bit.ly/9bb6hy>>.

Walker, J.D., S.H. Cotner, P.M. Baepler, and M.D. Decker. 2008. "A Delicate Balance: Integrating Active Learning into a Large Lecture Course," *CBE—Life Sci Educ* **7**(4): 361–367; online at <<http://www.lifescied.org/cgi/reprint/7/4/361>>.

Wood, W.B., and Handelsman, J. 2004. "Meeting Report: The 2004 National Academies Summer Institute on Undergraduate Education in Biology," *Cell Biol. Ed.* **3**: 215-217; online at <<http://bit.ly/dc7UtA>>.

Wood, W.B. 2003. "Inquiry-Based Undergraduate Teaching in the Life Sciences at Large Research Universities: A Perspective on the Boyer Commission Report," *Cell Biology Education* **2**: 112-116; online at <<http://bit.ly/b0zJ1G>>.

Wood, W.B. 2008. Editorial: "Sharing in the Classroom," *CBE Life Sci Educ* **7**(3): 263-264; online at <<http://bit.ly/auMTDE>>.

Wood, W.B. 2009. "Innovations in teaching undergraduate biology and why we need them." *Annual. Rev. Cell Dev. Biol.* **25**: 93-112; online at <<http://bit.ly/9IRDGp>>.

Wood, W.B. 2009. NRC panel presentation: "What is the State of Evidence in Discipline Based Education Research" click on "Bill Wood" at <<http://bit.ly/ciNwjQ>>.

Wood, W.B. 2009. "Revising the AP biology curriculum," *Science* **325**: 1627–1628; online as a 193 kB pdf at <<http://bit.ly/aPb2Vz>>.

Woodin, T., V.C. Carter, & L. Fletcher. 2010. "Vision and change in biology undergraduate education, a call for action— initial responses," *CBE Life Sci. Educ.* **9**(2): 71–73; online at <<http://bit.ly/eTo9eP>>.