NOTES

1. The Vision

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2. Susan R. Singer, Natalie R. Nielsen, and Heidi A. Schweingruber, eds., *Discipline-Based Education Research: Understanding and Improving Learning in Undergraduate Science and Engineering* (Washington, DC: National Academies Press, 2012).
3. Wendy K. Adams, Katherine K. Perkins, Noah S. Podolefsky, Michael Dubson, Noah D. Finkelstein, and Carl E. Wieman, "A New Instrument for Measuring Student Beliefs about Physics and Learning Physics: The Colorado Learning Attitudes about Science Survey," *Physical Review Special Topics: Physics Education Research* 2, no. 1 (2006): 010101.
4. For an extensive discussion of these topics, see James J. Duderstadt, *A University for the 21st Century* (Ann Arbor: University of Michigan Press, 2009).
5. J. Bransford et al., *How People Learn* (Washington, DC: National Academy Press, 2002); Singer et al., *Discipline-Based Education Research*.

6. See, for example, Scott Freeman, Sarah L. Eddy, Miles McDonough, Michelle K. Smith, Nnadozie Okoroafor, Hannah Jordt, and Mary Pat Wenderoth, "Active Learning Increases Student Performance in Science, Engineering, and Mathematics," *Proceedings of the National Academy of Sciences* 111, no. 23 (2014): 8410–8415.
7. P. Ross, "The Expert Mind," *Scientific American*, August 2006, 64; K. A. Ericsson et al., *The Cambridge Handbook of Expertise and Expert Performance* (Cambridge: Cambridge University Press, 2006).
8. E. Redish, *Teaching Physics with the Physics Suite* (New York: Wiley, 2003); Adams et al., "New Instrument"; K. K. Perkins, W. K. Adams, N. D. Finkelstein, S. J. Pollock, and C. E. Wieman, "Correlating Student Beliefs with Student Learning Using the Colorado Learning Attitudes about Science Survey," in *2004 Physics Education Research Conference*, ed. Jeffrey Marx, Paula Heron, and Scott Franklin (Melville, NY: American Institute of Physics, 2005).
9. More details can be found in Carl Wieman, "A New Model for Post-Secondary Education: The Optimized University," Campus 2020, British Columbia Ministry of Advanced Education, http://cwsei.ubc.ca/resources/files/BC_Campus2020_Wieman_think_piece.pdf.
10. Bob Uttl, Carmela A. White, Daniela Wong Gonzalez, "Meta-analysis of Faculty's Teaching Effectiveness: Student Evaluation of Teaching Ratings and Student Learning Are Not Related," *Studies in Educational Evaluation* (in press), doi.org/10.1016/j.stueduc.2016.08.007.
11. Carl Wieman, "A Better Way to Evaluate Undergraduate Teaching," *Change: The Magazine of Higher Learning* 47, no. 1 (2015): 6–15.
12. Wieman, "A Better Way."

2. The SEI Model for Achieving Change

1. Everett M. Rogers, *Diffusion of Innovations*, 5th ed. (New York: Free Press, 2003).
2. Michael Fullan, *The New Meaning of Educational Change*, 3rd ed. (New York: Teachers College Press, 2001); E. Seymour, "Tracking the Process of Change in U.S. Undergraduate Education in Science, Mathematics, Engineering, and Technology," *Science Education* 86 (2002): 79–105.
3. Rogers, *Diffusion of Innovations*, chap. 5.
4. John P. Kotter, *Leading Change* (Boston: Harvard Business Review Press, 1996).
5. Carl Wieman and Ashley Welsh, "The Connection between Teaching Methods and Attribution Errors," *Educational Psychology Review* 28 (2016): 645–648.

6. At CU, the funding arrangement was relatively complex, as it was designed to minimize the SEI's impact on the CU budget. In part, it involved the use of the author's salary money, unspent endowed chair funds that the author had accumulated, and some flexible funds in the central administration and campus budgets.

3. The Process of Making Change

1. The most recent call for proposals, conducted in 2010, is available online at www.colorado.edu/sei/about/funding.htm.
2. See, for example, the EOAS long-term plan, accessible online at www.eoas.ubc.ca/research/cwsei/courses.html.
3. More information about learning goals and various references are available through the website of the Carl Wieman Science Education Initiative. See the resource page at www.cwsei.ubc.ca/resources/learn_goals.htm.
4. Stephanie V. Chasteen, Steven J. Pollock, Rachel E. Pepper, and Katherine K. Perkins, "Transforming the Junior Level: Outcomes from Instruction and Research in E&M," *Physical Review Special Topics: Physics Education Research* 8, no. 2 (2012): 020107.
5. For more on peer instruction, see Eric Mazur, *Peer Instruction: A User's Manual* (Upper Saddle River, NJ: Prentice Hall, 1997); for more on think-pair-share, see Frank Lyman, "The Responsive Classroom Discussion: The Inclusion of All Students," in *Mainstreaming Digest*, ed. A. S. Anderson, 109–113 (College Park: University of Maryland, College of Education, 1981).
6. Michelle K. Smith, Francis H. M. Jones, Sarah L. Gilbert, and Carl E. Wieman, "The Classroom Observation Protocol for Undergraduate STEM (COPUS): A New Instrument to Characterize University STEM Classroom Practices," *CBE-Life Sciences Education* 12, no. 4 (2013): 618–627; additional resources can be found at www.cwsei.ubc.ca/resources/COPUS.htm.
7. Stephanie V. Chasteen, Bethany Wilcox, Marcos D. Caballero, Katherine K. Perkins, Steven J. Pollock, and Carl E. Wieman, "Educational Transformation in Upper-Division Physics: The Science Education Initiative Model, Outcomes, and Lessons Learned," *Physical Review Special Topics: Physical Education Research* 11 (2015): 020110.
8. See www.cwsei.ubc.ca/resources/surveys.htm for descriptions and links to learning attitudes about science surveys.
9. Smith et al., "Classroom Observation Protocol."
10. Carl Wieman and Sarah Gilbert, "The Teaching Practices Inventory: A New Tool for Characterizing College and University Teaching in Mathematics and Science," *CBE-Life Sciences Education* 13, no. 3 (2014): 552–569;

additional resources can be found at www.cwsei.ubc.ca/resources/TeachingPracticesInventory.htm.

4. Science Education Specialists: Agents of Change

1. For more on learning goals, see www.cwsei.ubc.ca/resources/learn_goals.htm.
2. Rachel E. Pepper, Stephanie V. Chasteen, Steven J. Pollock, and Katherine K. Perkins, "Facilitating Faculty Conversations: Development of Consensus Learning Goals," Paper presented at the Physics Education Research Conference 2011, Omaha, Nebraska, August 3–4, 2011, http://www.compadre.org/Repository/document/ServeFile.cfm?ID=11870&DocID=2718 (accessed December 22, 2016); Stephanie V. Chasteen, Katherine K. Perkins, Paul D. Beale, Steven J. Pollock, and Carl E. Wieman, "A Thoughtful Approach to Instruction: Course Transformation for the Rest of Us," *Journal of College Science Teaching* 40, no. 4 (2011): 24–30.
3. See www.cwsei.ubc.ca/resources/surveys.htm for examples.
4. For more on student engagement, see Erin S. Lane and Sara E. Harris, "A New Tool for Measuring Student Behavioral Engagement in Large University Classes," *Journal of College Science Teaching* 44, no. 6 (2015): 83–91. It describes the Behavioral Engagement Related to Instruction (BERI) protocol developed by Lane and Harris. For more on instructor practice, see Michelle K. Smith, Francis H. M. Jones, Sarah L. Gilbert, and Carl E. Wieman, "The Classroom Observation Protocol for Undergraduate STEM (COPUS): A New Instrument to Characterize University STEM Classroom Practices," *CBE-Life Sciences Education* 12, no. 4 (2013): 618–627.
5. Wendy K. Adams and Carl E. Wieman, "Development and Validation of Instruments to Measure Learning of Expert-like Thinking," *International Journal of Science Education* 33, no. 9 (2011): 1289–1312.
6. Stephanie V. Chasteen, Rachel E. Pepper, Marcos D. Caballero, Steven J. Pollock, and Katherine K. Perkins, "Colorado Upper-Division Electrostatics Diagnostic: A Conceptual Assessment for the Junior Level," *Physical Review Special Topics: Physics Education Research* 8, no. 2 (2012): 020108; Bethany R. Wilcox and Steven J. Pollock, "Validation and Analysis of the Coupled Multiple Response Colorado Upper-Division Electrostatics Diagnostic," *Physical Review Special Topics: Physics Education Research* 11, no. 2 (2015): 020130.
7. Smith et al., "Classroom Observation Protocol"; Lane and Harris, "New Tool."
8. The online course materials management system can be found at www.sei.ubc.ca.

9. For the use of clickers, see http://STEMclickers.colorado.edu; for the use of learning goals, see www.cwsei.ubc.ca/resources/learn_goals.htm; for SEI videos, see www.cwsei.ubc.ca/resources/SEI_video.html.
10. EOAS-SEI Times newsletter accessible at www.eoas.ubc.ca/research/cwsei/eossei-times.html.
11. See also www.eoas.ubc.ca/research/cwsei/courses.html.
12. Roger Fisher and William Ury, *Getting to Yes* (New York: Simon and Schuster Sound Ideas, 1987); John D. Bransford, Ann L. Brown, and Rodney R. Cocking, *How People Learn: Brain, Mind, Experience, and School* (Washington, DC: National Academies Press, 1999); Susan A. Ambrose, Michael W. Bridges, Michele DiPietro, Marsha C. Lovett, and Marie K. Norman, *How Learning Works: Seven Research-Based Principles for Smart Teaching* (Hoboken, NJ: John Wiley and Sons, 2010).
13. The training program schedule and materials are provided at www.cwsei.ubc.ca/resources/STLF-develop.htm.

5. What Was Achieved and What We Learned

1. Carl Wieman, "A Better Way to Evaluate Undergraduate Teaching," *Change: The Magazine of Higher Learning* 47, no. 1 (2015): 6–15.
2. A copy of the midway survey can be found at www.colorado.edu/sei/surveys/Sp10/SEI-FacultySurvey-Feb2010-PHYS.html.
3. Carl Wieman and Sarah Gilbert, "The Teaching Practices Inventory: A New Tool for Characterizing College and University Teaching in Mathematics and Science," *CBE-Life Sciences Education* 13, no. 3 (2014): 552–569.
4. Carl Wieman and Ashley Welsh, "The Connection between Teaching Methods and Attribution Errors," *Educational Psychology Review* 28 (2016): 645–648.
5. Stephanie V. Chasteen, Bethany Wilcox, Marcos D. Caballero, Katherine K. Perkins, Steven J. Pollock, and Carl E. Wieman, "Educational Transformation in Upper-Division Physics: The Science Education Initiative Model, Outcomes, and Lessons Learned," *Physical Review Special Topics: Physical Education Research* 11 (2015): 020110.
6. The 2012 and 2013 updates can be found at www.cwsei.ubc.ca/departments/earth-ocean.htm.
7. Items listed in this table are expanded upon in the agreement document, accessible at www.cwsei.ubc.ca/resources/files/Course_Transform_Expectations.pdf.
8. To see more details on this course, consult its webpage at www.cwsei.ubc.ca/departments/earth-ocean_TA.htm.

9. Previous issues of the newsletter can be accessed at www.eoas.ubc.ca/research/cwsei/eossei-times.html.
10. See the webpage at www.eoas.ubc.ca/research/cwsei.
11. This video series can be accessed at http://blogs.ubc.ca/wpvc.
12. Wieman and Gilbert, "Teaching Practices Inventory."
13. For more information on the survey and its findings, see Carl Wieman, Louis Deslauriers, and Brett Gilley, "Use of Research-Based Instructional Strategies: How to Avoid Faculty Quitting," *Physical Review Special Topics: Physics Education Research* 9, no. 2 (2013): 023102.
14. Chasteen et al., "Educational Transformation."
15. For more on the University of Colorado Learning Assistant Program, see https://laprogram.colorado.edu/.

6. The Post-Mortem: What Worked, What Didn't, and Why

1. John P. Kotter, *Leading Change* (Boston: Harvard Business Review Press, 1996).
2. Carl Wieman, "A Better Way to Evaluate Undergraduate Teaching," *Change: The Magazine of Higher Learning* 47, no. 1 (2015): 6–15.
3. For a thorough introduction to this concept, see Leon Festinger, *A Theory of Cognitive Dissonance*, vol. 2 (Palo Alto, CA: Stanford University Press, 1962).
4. A notable example of a study discussing this problem is Charles Henderson and Melissa H. Dancy, "Increasing the Impact and Diffusion of STEM Education Innovations," Invited paper for the National Academy of Engineering, Center for the Advancement of Engineering Education Forum, Impact and Diffusion of Transformative Engineering Education Innovations, 2011.

Appendix 1. SEI Course Transformation Guide

1. G. Gibbs and C. Simpson, "Conditions under Which Assessment Supports Student Learning," *Learning and Teaching in Higher Education* 1 (2004): 3–31.
2. Effective techniques involve designing assignments to be of obvious benefit to the learning of the student; they should have substantial overlap with the exams and have some portions of the assignment that involve "explaining in your own words."
3. S. Bonham, "Reliability, Compliance, and Security in Web-Based Course Assessments," *Physical Review Special Topics: Physics Education Research* 4 (2008): 010106.

4. C. Crouch and E. Mazur, "Peer Instruction: Ten Years of Experience and Results," *American Journal of Physics* 69 (2001): 970–977.
5. See "Just-in-Time Teaching," Department of Physics, Indiana University—Purdue University Indianapolis, 2006, http://jittdl.physics.iupui.edu/jitt.
6. K. Topping, "Peer Assessment between Students in Colleges and Universities," *Review of Educational Research* 68, no. 3 (1998): 249–276.
7. B. Gilley and B. Clarkston, "Collaborative Testing: Evidence of Learning in a Controlled In-Class Study of Undergraduate Students," *Journal of College Science Teaching* 43, no. 3 (2014): 83–91; G. Rieger and C. Heiner, "Examinations That Support Collaborative Learning: The Students' Perspective," *Journal of College Science Teaching* 43, no. 4 (2014): 41–47.