Gateway Science Education: A Starting Point
Select References to Pedagogy, Assessment, and Innovative Instruction

Culture of Science/Future of Education

Anderson, W. A., Banerjee, U., Drennan, C. L., Elgin, S. C. R., Epstein, I. R., Handelsman, J., . . . Warner, I. M. (2011). **Changing the Culture of Science Education at Research Universities.** *Science, 331* (6014), 152-153. (*The authors, Howard Hughes Medical Institute professors at various colleges, propose seven initiatives colleges can adapt to improve the reward system for teaching at research institutions.*)

Hobson, A. (2001). **Teaching Relevant Science for Scientific Literacy: Adding Cultural Context to the Sciences.** *Journal of College Science Teaching, 30*(4), 238-43. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&db=eric&AN=EJ622152&site=ehost-live (*Starting with assertion that most Americans are scientifically illiterate, author proposes 5 principles for creating liberal-arts science courses (in high school or college) with socially- and culturally-relevant examples to improve student learning and science literacy. He provides an application of this approach through a case study of how to teach global warming concepts.*)

Arum, R. and Roksa, J. (2011) **Academically Adrift: Limited Learning on College Campuses**. University Of Chicago Press, January 15, 2011. (*Recent publication by two prominent sociologists suggests students' learning gains are not significant at many colleges because of a lack of rigor in course work. Analysis is based on data from student surveys and transcript analysis along with the gains on the Collegiate Learning Assessment for 2,300 students of traditional college age enrolled at a range of four-year colleges and universities*.)

Pedagogy and Teaching Strategies

Chickering, Arthur W. and Gamson, Zelda F. **Applying the Seven Principles of Good Practice for Undergraduate Education – New Directions for Teaching and Learning**. Jossey-Bass Inc. Publisher (September 1991). (*Pedagogical principles and structure for redesigning courses. Faculty may find it useful to consult these guidelines as they prepare their GSI proposal, describing how the seven principles would be addressed in their projects if funded*.)

Felder, R.M. and Brent, R. (2009) **Active Learning: An Introduction.** ASQ Higher Education Brief, 2(4), 1-5. Retrieved from http://www4.ncsu.edu/unity/lockers/users/f/felder/public/Papers/ALpaper(ASQ).pdf (*FAQ about active learning, what you can do, and what you can get your students to do.*)

Handelsman, J**.**, Miller, S, and Pfund, C. **Scientific Teaching.** W. H. Freeman; First Edition (December 15, 2006). (*HHMI Professor Jo Handelsman and colleagues at the Wisconsin Program for Scientific Teaching (WPST) distill key findings from education, learning, and cognitive psychology and translate them into six chapters of research points and practical classroom examples. Recommendations have been tested in the National Academies Summer Institute on Undergraduate Education in Biology and through the WPST. Encourages readers to approach teaching in a way that captures the spirit and rigor of scientific research and contributes to transforming how students learn science.*)

Napier, N. P., Dekhane, S., and Smith, S. (2011). **Transitioning to Blended Learning: Understanding Student and Faculty Perceptions**. *Journal of Asynchronous Learning Networks, 15* (1), 20-32. Retrieved from http://sloanconsortium.org/jaln/v15n1/transitioning-blended-learning-understanding-student-and-faculty-perceptions (*Describes conversion of an introductory computing course to a blended learning model that combines online and in class pedagogical approaches at Georgia Gwinnet College, a small, public liberal arts institution. Blended learning reduced face-to-face instruction by incorporating rich, online learning experiences into the curriculum. Student performance in the traditional and blended learning sections of the course was comparable; students in the blended learning sections maintained levels of interaction with their instructor and expressed satisfaction with the model.)*

Rossiter, D., Petrulis, R., & Biggs, C. A. (2010). **A Blended Approach to Problem-based Learning in the Freshman Year**. *Chemical Engineering Education, 44* (1), 23-29. Retrieved from http://cee.che.ufl.edu/Journals/Winter%202010%20v44.1/Rossiter441.html (D*escribes 5-year transformation of a first-year chemical engineering course at the University of Sheffield, Sheffield, UK, based on evidence from student feedback. Course has evolved to incorporate problem-based learning and a blended learning approach with the use of online learning tools (quizzes and tutorials) as a mechanism for providing fundamental knowledge and developing problem solving skills of less advanced students. Students were exposed to the way engineers work, think and communicate their ideas. Also introduced to the fundamentals of the discipline. These changes transformed the course from one with a high failure rate where students were struggling to grasp the key concepts, to a successful module with significantly lower failure rate and positive student feedback.*)

Verginis, I., Gogoulou, A., Gouli, E., Boubouka, M., & Grigoriadou, M. (2011). **Enhancing Learning in Introductory Computer Science Courses through SCALE: An Empirical Study**. *IEEE Transactions on Education, 54*(1), 1-13. Retrieved from http://dx.doi.org/10.1109/TE.2010.2040477 (*Reviews literature of the methods and systems used to support and promote the learning process in introductory computer science courses. Describes the use of a Web-based, adaptive, activity-oriented learning environment: Supporting Collaboration and Adaptation in a Learning Environment (SCALE). SCALE promotes active learning and provides immediate evaluation to students, allowing them to establish a foundation for more advanced study. No significant difference found between the experimental (SCALE users) and the control group in a pretest, but students of the experimental group outperformed the control group students in a post-test. Students who participated as members of the experimental group expressed their satisfaction and characterized SCALE as a valuable educational tool.*)

Assessment

Lynd-Balta, E. (2006). **Using Literature and Innovative Assessments to Ignite Interest and Cultivate Critical Thinking Skills in an Undergraduate Neuroscience Course**. *CBE Life Sciences Education, 5*(2), 167-174. (C*ase study in which scientific topics for a neuroscience course (e.g., ALS) are introduced through non-science literature (e.g., Tuesdays with Morrie). Students write a reaction paper and information pamphlet on topic. The purpose is to get students engaged with content, develop their critical thinking skills, and show how scientific topics relate to real-world*

situations. Author compares data on student learning (final exams) between semesters in which method was used and was not used.)

Bioethics

UK Centre for Bioscience: Ethics in the Biosciences Briefing
http://www.bioscience.heacademy.ac.uk/ftp/resources/briefing/ethicsbrief.pdf
(Brings together references and resources in specific areas of learning and teaching in the biosciences. With resources recommended by the bioscience teaching and learning community, this will be of use and interest both to those with experience and those new to the topic. Each section of the briefing is introduced by an expert in that area and reflects the author's individual style and preference.)
For more information please contact: Holly Taylor, PhD, MPH
Assistant Professor, Department of Health Policy and Management, Johns Hopkins Bloomberg School of Public Health, Johns Hopkins Berman Institute of Bioethics, htaylor@jhsph.edu

Biology

Bell, E. (2011). **Using Research to Teach an Introduction to Biological Thinking**. *Biochemistry and Molecular Biology Education, 39*(1), 10-16. Retrieved from http://dx.doi.org/10.1002/bmb.20441
(*Course involves students in designing original research projects and then, in the laboratory, the experiments are carried out and analyzed and presented to the class by the students. Focus is on redesigning a single enzyme and measuring its resultant activity. Good hands-on approach that develops useful laboratory skills. Only useful in small groups (32) however*.)

Brewer, C. (2009) **Vision and Change in Undergraduate Biology Education: A Call to Action**. AAAS. Retrieved from http://www.visionandchange.org/ .
(*Extensive report from AAAS and supported by NSF, covering many areas regarding undergraduate biology training. Topics include: new challenges for faculty, foundations of undergraduate biology, rethinking the curriculum, the student centered classroom, integrating undergraduate research experience and developing future faculty. Lots of examples of practices that have been implemented*).

Porter, Sandra, Day, Joseph, McCarty, Richard E., Shearn, Allen, Shingles, Richard, Mulvihill, Charlotte, Fletcher, Linnea, Murphy, Stephanie, and Pearlman, Rebecca (2007). **Exploring DNA Structure with Cn3D***.* Cell Biology Education 6: 65-73. *(Published results of Hopkins faculty who do the same exercise in General Biology as that described by Zhang, using the Exploring DNA program developed by Geospiza*.)

Wood, W. B. (2009). **Innovations in Teaching Undergraduate Biology and Why We Need Them**. *Annual Review of Cell and Developmental Biology, 25*, 93-112.
http://www.annualreviews.org/doi/full/10.1146/annurev.cellbio.24.110707.175306?url_ver=Z39.88-2003&rfr_id=ori:rid:crossref.org&rfr_dat=cr_pub%3dpubmed
(*Review of the history and current status of teaching undergraduate science and biology in particular. The review combines learning theory with old practices and new practices to evaluate their effectiveness. The paper outlines a number of practices for increasing student learning*.)

Zhang, X. (2011). **Exploring Cystic Fibrosis Using Bioinformatics Tools: a Module Designed for the Freshman Biology Course**. *Biochemistry and Molecular Biology Education, 39*(1), 17-20. Retrieved from http://dx.doi.org/10.1002/bmb.20460
(*Course uses online bioinformatic tools to search databases and construct structural models of proteins using the program, Cn3D.*)

Chemistry

Chambers, Kent A. and Blake, Bob. **Enhancing Student Performance in First-Semester General Chemistry Using Active Feedback through the World Wide Web**
J. Chem. Educ., 2007, 84 (7), 1130 DOI: 10.1021/ed084p1130. Retrieved from http://pubs.acs.org/doi/abs/10.1021/ed084p1130 (*Web-based pre-lecture questions allow the instructor to evaluate students' prior knowledge and understanding of fundamental concepts. Post-lecture questions permit evaluation of how well the class is mastering individual concepts. By analyzing student submissions prior to each class meeting, instructor can tailor each lecture to address and reinforce the concepts with which the class as a whole is having difficulty. Comparing students in lectures using this pedagogical technique with two control groups, the data show that the student academic performance of the experimental group was significantly higher (*$p < 0.05$*) than both control groups.*)

Johnstone, A.H. **You Can't Get There from Here,** J. Chem. Educ., 2010, 87 (1), 22-29 DOI: 10.1021/ed800026d. Retrieved from http://pubs.acs.org/doi/full/10.1021/ed800026d
(*Citing surveys about common learning problems in chemistry from 1970 through 1981, information overload is cited as the persistent common problem areas for chemistry students. Paper suggests abandoning problematic topics because their difficulty is driving students away from the discipline at the introductory level. Suggests a model by which a pragmatic revision can take place without dilution or trivialization of chemistry as a discipline*.)

Holme, T., Lowery Bretz, S., Cooper, M., Lewis, J., Paek, P., Pienta, N., Stacy, A., Stevens, R., and Town, M. **Enhancing the Role of Assessment in Curriculum Reform in Chemistry.**
Chem. Educ. Res. Pract., 2010, 11, 92-97 DOI: 10.1039/C005352J. Retrieved from http://pubs.rsc.org/en/content/articlelanding/2010/rp/c005352j (*Use of multiple assessment strategies that measure student problem solving, metacognition, and cognitive development within the chemistry content at the college level and evaluate students in affective aspects of learning, can inform decision making about teaching innovation. Summaries of how these new tools may be combined and what measures arise from such combinations are presented.*)

Eilks, Ingo and Byers, Bill. **The Need for Innovative Methods of Teaching and Learning Chemistry in Higher Education - Reflections from a Project of the European Chemistry Thematic Network**.
Chem. Educ. Res. Pract., 2010, 11, 233-240, DOI: 10.1039/C0RP90004D. Retrieved from http://pubs.rsc.org/en/content/articlelanding/2010/rp/c0rp90004d (*Summarizes the conclusions of a working group established by the European Chemistry Thematic Network (ECTN). Aim was to identify potential areas for innovative approaches to the teaching and learning of chemistry in higher education and survey good practice throughout the EU. Contains brief discussion of ten distinct areas identified by the working group in which innovation offers opportunities to enhance the student learning experience in higher level chemistry education.*

Importance of improved training in pedagogy and pedagogical content knowledge for new lecturers is also stressed.)

Eilks, Ingo and Byers, Bill, eds**. Innovative Methods of Teaching and Learning Chemistry in Higher Education.** ISBN: 9781847559586, Eisenhower Stacks, QD49.E85 I56 2009 QUARTO. http://findit.library.jhu.edu/findit-dev/go/3670619 (*Longer version of article above*.)

Mathematics/Statistics

Cholkar, C. and Deshpande, M. **Useful Data for Teaching Statistics from Hockey World Cup Matches**, Teaching Statistics 26(1), Spring 2004. Retrieved from http://content.epnet.com/pdf25_26/pdf/2004/D8Y/01Feb04/11702015.pdf?T=P&P=AN&K=11702015&EbscoContent=dGJyMNXb4kSeqLc4yOvsOLCmr0mep69Sr6i4TbKWxWXS&ContentCustomer=dGJyMPGps02zqK5KuePfgeyx%2BEu3q64A&D=a9h
(Uses *data from a major sports event as a vehicle for common statistical analyses*. *Covers these concepts: illustration of rank correlation, illustration of correlation, and fitting a theoretical probability of distribution.*)

Colley, S. J. (2011). **What is Mathematics and Why Won't It Go Away?** *PRIMUS, 21*(3), 211-224. Retrieved from
http://www.informaworld.com/openurl?genre=article&id=doi:10.1080/10511970902855605
(*Reports on a first-year college level seminar that weaves mathematical proof and problem-solving together with discussions of cultural, philosophical, and aesthetic issues surrounding mathematics*.)

Freeman J, Collier S, Staniforth D, Smith K. **Innovations in Curriculum Design: a Multi-disciplinary Approach to Teaching Statistics to Undergraduate Medical Students**. BMC Med Educ. 8(28), 2008. Retrieved from http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2397402/
(*Statistics are increasingly taught as part of the medical curriculum; it is common for students to dislike and under-perform in the area. A statistician, clinician, and educational team re-conceptualize the syllabus and focused on developing different methods of delivery. New teaching materials, including videos, animations, and contextualized workbooks, were designed and produced, placing greater emphasis on applying statistics and interpreting data. Employing a variety of media and emphasizing interpretation rendered teaching, learning and understanding statistics more people-centered and relevant and resulted in better student learning outcomes.*)

Gelman, A. **A Course on Teaching Statistics at the University Level**. American Statistician 59(1), Feb. 2005. Retrieved from http://www.jstor.org/stable/27643608 (*Describes new course developed for statistics graduate teaching assistants; combines practice in statistics demonstrations and drills, discussion of teaching strategies, and feedback on classroom teaching. Goal is to help graduate students develop a comfort level with engaging their students in active learning.)*

Hulsizer, M. and Woolf L. **A Guide to Teaching Statistics: Innovations and Best Practices**. Chichester, UK: Wiley-Blackwell, 2009. Retrieved from https://catalyst.library.jhu.edu/catalog/bib_2884181 (*Covers a range of statistics education and assessment topics; includes classroom exercises, pedagogical tools, and computer applications designed to enhance active learning. Topics include descriptive, inferential, and multivariate statistics as well as the importance of using real data in the classroom, the role of ethics and diversity in statistics, and the effectiveness of online statistical education.*)

Physics

Lasry, N. (2008). **Clickers or Flashcards: Is There Really a Difference?** Physics Teacher, 46(4), 242-244. Retrieved from http://dx.doi.org/10.1119/1.2895678
(*Classroom study comparing the differences in student learning between a Peer Instruction group using clickers and a Peer Instruction group using flashcards; using the assessed student learning differences, the paper describes differences in teaching effectiveness between clickers and flashcards.)*

Wrinkle, C. S., & Manivannan, M. K. (2009). **Application of the K-W-L Teaching and Learning Method to an Introductory Physics Course**. *Journal of College Science Teaching, 39* (2), 47-51. Retrieved from
http://www.nsta.org/publications/browse_journals.aspx?action=issue&id=10.2505/3/jcst09_039_02
(*Discusses how the K-W-L method* helped students think about what they* know *about a topic as a precursor to questioning their own ideas and preconceptions about physics. The K-W-L method of teaching is a simple method that actively engages students in their own learning.* ***K*** *= find out what students Know about a topic;* ***W*** *= find out what students Want to know;* ***L*** *(used after students complete their activities) = find out what students have Learned. After gathering data in class, students applied the data to what they learned from the laboratory information.*)

Engineering

Felder, Richard M., Brent, Rebecca, Prince, Michael J. **Engineering Instructional Development: Programs, Best Practices, and Recommendations**. *Journal of Engineering Education*, 100 (1), Jan. 2011, 89-122. Retrieved from http://www.jee.org/2011/January/05
(*Presents variety of options for faculty development, ranging from informal small-group activities and mentoring to highly structured workshops and courses. Also suggests strategies for organizing faculty development activities to make them as effective as possible*.)

Johri, Aditya and Olds, Barbara M., **Situated Engineering Learning: Bridging Engineering Education Research and the Learning Sciences**. *Journal of Engineering Education*, 100 (1), Jan. 2011, 151-185. Retrieved from http://www.jee.org/2011/January/05 (*Authors provide an overview of situated learning theory, which proposes learning must be situated within authentic activity, context, and culture; they make a case for its application to engineering education.*)

Professional Organizations/Publications/Exemplary University Programs

From Analysis to Action – NAS - http://www.nap.edu/catalog.php?record_id=9128

How People Learn – http://www.nap.edu/catalog.php?record_id=9853

Science for All Americans – http://www.project2061.org/publications/sfaa/default.htm

Biology

American Society of Microbiology Conference on Undergraduate Education:
http://www.asmcue.org/

Journal of Microbiology & Biology Education: http://journals.sfu.ca/asm/index.php/jmbe

Life Sciences Education: http://www.lifescied.org/

Biochemistry and Molecular Biology Education
http://onlinelibrary.wiley.com/journal/10.1002/%28ISSN%291539-3429

Bio2010 http://www.nap.edu/openbook.php?isbn=0309085357

Chemistry

American Chemical Society:
http://portal.acs.org/portal/acs/corg/content?_nfpb=true&_pageLabel=PP_SUPERARTICLE&node_id=1584&use_sec=false&sec_url_var=region1&__uuid=57153db7-6b38-4925-9c57-c2d15cec59ab

University of Wisconsin education program: http://ice.chem.wisc.edu/

Journal of Chemical Education: http://pubs.acs.org/journal/jceda8

Mathematics and Statistics

American Statistical Association's (ASA): http://www.amstat.org/education/index.cfm
Mathematical Association of America: http://www.maa.org/subpage_3.html

Physics

Institute of Physics (IOPscience) Physics Education: http://iopscience.iop.org/0031-9120/

Engineering

Journal of Engineering Education: http://www.jee.org/about-jeel