Suggested Resources for Scholarly Teaching and for the Scholarship of Teaching and Learning
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These are some of my favorite resources of informing scholarly teaching (ST) and the scholarship of teaching and learning (SOTL). This list is focused on the needs of college biology faculty. It is highly selective and somewhat idiosyncratic in that many more items are relevant and could have been included.

Scholarly teaching, as I use it here, means using pedagogical practices that are informed by a range of SOTL results and that approximate the course-relevant, current best practices as seen from a national perspective. There is a gradient of scholarly teaching that starts with evidence-based, active learning practices and expands to incorporate a range of frameworks that can further improve student learning. Scholarly teaching moves easily to incorporate various classroom assessment techniques (CATS), including concept inventories and other unit or course pre- and post-tests. As assessment becomes more informed by the current state of the SOTL literature, the focus may shift to producing new results for use by others, or SOTL. When this possibility first emerges, the faculty member must begin the institutional Human Subjects processes.

It is common to begin in SOTL by asking a question about one’s own class and moving fairly directly into possible changes that might improve student learning, together with ways that one might measure or document the effects, if any, of changes as they are made. This is a very good way to get started and some very important results have emerged from this process. Once this initial focus is clear, it will often be important to explore the literature for alternative hypotheses that might be combined with yours to expedite the improvement and documentation of learning. This can also help us understand alternative interpretations and confounding variables.

PART I: GREAT FOR BOTH ST AND SOTL

Reviews--Large changes come from adopting active learning:


National Research Council, Board On Science Education. 2008. Workshop on linking evidence and promising practices in STEM undergraduate education. [See links below. Includes some reviews and great examples (see especially the ones by Beichner, by Cummings, by Grant and by Wood).]


Three essentials:

Science Education Resource Center (SERC). Teaching methods. Available from: http://serc.carleton.edu/sp/library/pedagogies.html [This site provides descriptions and supporting material (usually including example activities) for over 50 different active learning pedagogies as applied in science. The SERC site as a whole is worth a look: http://serc.carleton.edu/index.html]

Handelsman, J., S. Miller, and C. Pfund. 2006. Scientific teaching. W.H. Freeman, New York, NY. [This is perhaps the single best primer for teaching biology at the college level. The authors summarize some key research
findings and provide examples of classroom applications with a strong focus on active learning. The book is based in part on the resources used in the National Academies Summer Institute on Undergraduate Education in Biology. Finally, at 208 pages, it is short but not too short.]

Mintzes, J. J., and W. H. Leonard (ed.). 2006. Handbook of college science teaching. National Science Teachers Association. NSTA Press, Arlington, VA. [This book is my suggestion as another essential read for both ST and SOTL. In both contexts, it provides key alternative ways for understanding students’ difficulties in learning biology and what is known about how to apply them. It is essential to read the chapters for the learning perspective, whether or not the science content is applicable to your interests. For example, read Constructive Developmental Pedagogy in Chemistry as introduction to thinking about learning in this framework (one of the most important), whether or not you find the chemistry ideas directly relevant. There are 38 chapters, each written by one or two experts. They include: 1. Science Anxiety (Mallow); 2. Attitudes in Biology (French); 3. Motivation (Glynn & Koballa); 4. Experiential Learning in a Large Biology Course (Druger); 7. Concept Mapping (Mintzes); 8. Peer Instruction (Godbey et al.); 11. Developing Scientific Reasoning in Biology (Lawson); 12. Learning Science and Science of Learning (Novak); 13. Conceptually Sequenced Genetics Unit (Crow & Harless); 15. Active Learning (Ueckert & Gess Newsome); 18. Case Studies (Herreid); 19. Converting Labs from Verification to Inquiry (French & Russell); 20. Constructive Developmental Pedagogy in Chemistry (Scharberg); and 31. Applying Conceptual Change Strategies (Stern et al.).]

Assessments of learning and teaching:

A fully developed assessment plant for fostering learning would include several approaches that operate on different timescales. It is important to glean feedback multiple times during each class period using, for example, write pair share or “clickers” or both. These are most effective if you adapt the flow of the class to the feedback you obtain. Techniques to help you gain information to use in refining your plan for the next class period could include “muddiest point” (see Angelo and Cross) or “just-in-time teaching.” Concept inventories and knowledge surveys can be designed or modified for use as pre- and post-test surveys given both before and after each unit and for the course as a whole. Using a range of practices can also be very helpful in designing, piloting and refining and then assessing SOTL interventions. Grant’s study (2008, 2009) is currently my favorite example from biology of the use of assessments to seriously redesign instruction and thereby remarkably improve learning. The following provide a few good starting places.

Three overall guides (each is essential):


National Institute for Science Education. Field-tested learning assessment guide for science, math, engineering, and technology (FLAG). Available from: http://www.flaguide.org/ [“…offers broadly applicable, self-contained modular classroom assessment techniques (CATs) and discipline-specific tools for STEM instructors interested in new approaches to evaluating student learning, attitudes and performance.” Nice.]


Clickers (electronic personal response systems):


Just-in-time teaching:


[“jITT is a teaching and learning strategy based on the interaction between web-based study assignments and an active learner classroom. Students respond electronically to carefully constructed web-based assignments which are due shortly before class, and the instructor reads the student submissions “just-in-time” to adjust the classroom lesson to suit the students’ needs…”]


Concept inventories and knowledge surveys:

These groups have been striving for many years to get us of the US National Academies of Science and Engineering. Two overviews from the U.S. National Academies: Innovating at the margins: A case study of teacher learning in improving undergraduate education. Workshop. National Research Council Board On Science Education. Link for download at: http://www7.nationalacademies.org/bose/PP_Commissioned_Papers.html

An instructive example of the use of formative and summative assessment to make a big difference in learning:


More books from the Society for College Science Teachers:

The SCST is an affiliate of the National Science Teachers Association. SCST publishes the Journal on College Science Teaching (JCST), has published a number of books on college science teaching via the NSTA, and is a good place to watch for more resources. The books include (besides those listed above):


Two overviews from the U.S. National Academies:

The National Research Council is the operational arm of the US National Academies of Science and Engineering. These groups have been striving for many years to get us to take undergraduate learning seriously and to change the ways in which science is usually taught. Because of the stature of the National Academies, these are not only good ideas for us to consider, but also provide some great sources for quotes to use with your colleagues and administrators. Note that books from the National Academies Press can be downloaded as free PDFs.


Two background items worth serious contemplation:

Seymour, E., and N. M. Hewitt. 1997. Talking about leaving: Why undergraduates leave the sciences. Westview Publishing Co., Nashville, TN. [Over half of the students who entered college declaring an intention to major in science ultimately majored in something else. They do not differ appreciably from those who stay with regard to entering qualifications or introductory science grades. Of those who leave, about 90% complain of ineffective science teaching as do about 75% of senior science majors. This finding held true across a wide variety of institutions. Very helpful in convincing ourselves and others that we have a big problem.]

Tobias, S. 1990. They’re not dumb, they’re different: Stalking the second tier. Research Corporation for Science Advancement, Tuscan, AZ. [Why do college students abandon science majors? The title says it all.]

PART II: THE SCHOLARSHIP OF TEACHING AND LEARNING

Some types of SOTL:


An essential overview of the current state of STEM SOTL:

Again, note that because the NRC is the operational arm of the National Academies, this material may carry
special weight with your colleagues and administration. Much of it is really good, too.


**Primers for STEM SOTL: Physics Education Research (PER):**

All STEM scholars planning SOTL projects should study this series carefully. This is easy since it is available as free PDFs! The key points lie not in the science content, but rather on the SOTL research methods and perspectives that are the focus of the articles. PER is by far the best-developed and most mature SOTL program in any field. Approximately 85 Physics Department have PER research programs and several of these offer a PhD in Physics with the dissertation in PER. (See http://www.per-central.org/programs/).


**Zou, X.** [Forthcoming.] An introduction to quantitative research methods in physics education.

**Primers for STEM SOTL from medicine and chemistry:**


**Primers for STEM SOTL from the National Science Foundation (NSF):**

The National Science Foundation has been working intensely to foster better STEM education at all levels and to foster better and more cumulative research on improving such learning. These three items are not focused directly on undergraduates but are still quite relevant.


**A few alternative interpretive frameworks [highly selective]:**

**Active Learning.**

It will make a big difference (see above). It is well known that new SOTL projects should be using some other frameworks to diagnose the barriers to learning and then attempt to address them. This will often use active learning designed to address the proposed problems. But just using active learning and showing it works is no longer very interesting.
Getting a grip.

If you don’t keep alternative frameworks in front of you they will bite you in the behind.


What mature SOTL yields in STEM.

Physics as the best example: misconception-focused inventories, pre- and post-testing, normalized gains and clear comparisons among pedagogies.


Misconceptions and alternative conceptions.

These are so difficult to change that much of science education, even at the college level, produces very little fundamental change in conceptual understanding. The core of what we need to do is called conceptual change. I include two videos, in case you or your colleagues need gut level convincing.


Duit, R. 2009a. Bibliography – STCSE: Students’ and teachers’ conceptions and science education. www.ipn.uni-kiel.de/aktuell/stcse/stcse.html [8,400 citations! Download and use the keyword search (see Duit 2009b for keywords) and find common misconceptions for your courses and see what has been tried to fix them.]


Grant, B. W. 2008. Practitioner research as a way of knowing: A case study of teacher learning in improving undergraduates’ concept acquisition of evolution by natural selection. Workshop on Linking Evidence and Promising Practices in STEM Undergraduate Education http://www7.nationalacademies.org/bose/PP_Commissioned_Papers.html [Great example. Found that students often “remained highly resistant to instruction, and often defended their misconceptions using course appropriate terminology, but incorrectly, on the course final exam … many had hijacked course content in service of their misconceptions.” Re-sorted to asking them in “guided discussions and turn-to-your neighbor activities to visualize and reflect upon the kinds of evidence and arguments I needed to present that would help them to understand …” Worked.]

Harvard-Smithsonian Center for Astrophysics. 1987. A private universe. Video. Distributed by Annenberg Media. http://www.learner.org/resources/series28.html ["With its famous opening scene at a Harvard graduation, this classic of education research brings into sharp focus the dilemma facing all educators: Why don’t even the brightest students truly grasp basic science concepts?"]

Harvard-Smithsonian Center for Astrophysics. 1997. Minds of our own. Video. Distributed by Annenberg Media at http://www.learner.org/resources/series26.html ["Why is it that students can graduate from MIT and Harvard, yet not know how to solve a simple third-grade problem in science: lighting a light bulb with a battery and wire? Beginning with this startling fact, this program systematically explores many of the assumptions that we hold about learning to show that education is based on a series of myths … The program takes a hard look at why teaching fails …" Watch the sections on photosynthesis and weep.]


Neo-Piagetian development: from concrete to formal and post-formal reasoning.

Differences among students in their current approach to reasoning frequently, perhaps usually, have major effects on their achievement in STEM courses unless the faculty member is quite aware of the differences and builds in mechanisms such as learning cycles. Amazingly, the tests used to measure reasoning do not depend on knowing any science content. It seems to me likely that failure to control for reasoning level will unnecessarily increase the amount of unexplained variance in your SOTL results. I suspect
that there will often be an important interaction term such that a given intervention works much better for students at particular levels.

Arons, A. B. 1976. Cultivating the capacity for formal operations: Objectives and procedures in an introductory physical science course. Am J Physics 44: 834-838. [Why students often do not really grasp multiplication and ratios when involved in understanding scientific concepts (such as area and density) and what can be done about it. But not quickly.]

Herron, J. D. 1975. Piaget for chemists: Explaining what “good” students cannot understand. J Chem Educ. 52:146-150. [Basically, students using concrete operations can only understand what they can directly observe, so density is out without much help. And it only gets worse. Read this and Arons for hypotheses as to what interventions you need to design, especially for molecular aspects of biology.]

Lawson, A. E., D. L. Banks, and M. Logvin. 2007. Self-efficacy, reasoning ability, and achievement in college biology. J Research in Science Teaching 44:706-724. [Using course final grade as the dependent variable with post-test scores for reasoning and self-efficacy estimates and ACT/SAT score: Post-test reasoning was the strongest predictor of final course grade, accounting for 32% of the variance. This article includes examples of multiple choice questions from introductory biology that typically cannot be done by students who have not reached higher levels of reasoning.]


Ward, C. R., and J. D. Herron. 1980. Helping students understand formal chemical concepts. J Research in Science Teaching 17:387-400. ["No concrete operational student received a grade higher than B; 74% of them received a D or F as did only 25% of the formal students." (p 396) “…the performance difference between concrete and formal students on formal questions is substantially reduced by introducing the learning cycle into the laboratory instruction. This gain by the concrete students is accomplished with no detrimental effect on the performance of the formal students. These results were obtained in a situation where instructional time was fixed. If the material were presented in a mastery learning setting with flexible time periods, the level of achievement by concrete students would likely improve even more.” (p 397) Learning cycle: Experience and exploration of patterns first; concepts only later; much structured social interaction; concepts then discussed; concepts applied to similar situations (p 388, 391).]

Learning to think, read, and communicate in a discipline.

It has become clear that we must teach these skills explicitly and cannot depend on the students knowing how to do them when they arrive in our classes. When we build this in appropriately, our SOTL interventions are likely to be more effective. This group of citations is heterogeneous, so examining one is not a substitute for the next. Each helps define the problems in ways that will help with effective change.

Meyer, J. H. F., and R. Land (ed.). 2006. Overcoming barriers to student understanding: Threshold concepts and troublesome knowledge. Routledge, New York, NY. [“…in certain disciplines there are “conceptual gateways” or “portals” that lead to previously inaccessible, and initially perhaps “troublesome,” ways of thinking …” Includes a chapter on threshold/troublesome concepts in biology.]


Intellectual Development, Critical Thinking, Effective Communication & Self Authorship.

This is the most important framework we have for seeing why students usually do not master critical-thinking and related skills and for redesigning pedagogy to make deep differences in these higher order outcomes. Perry’s book initiated what has become a major research program or set of programs (see Hofer & Pintrich, 2002). Baxter Magolda’s books are great recent starting points.


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