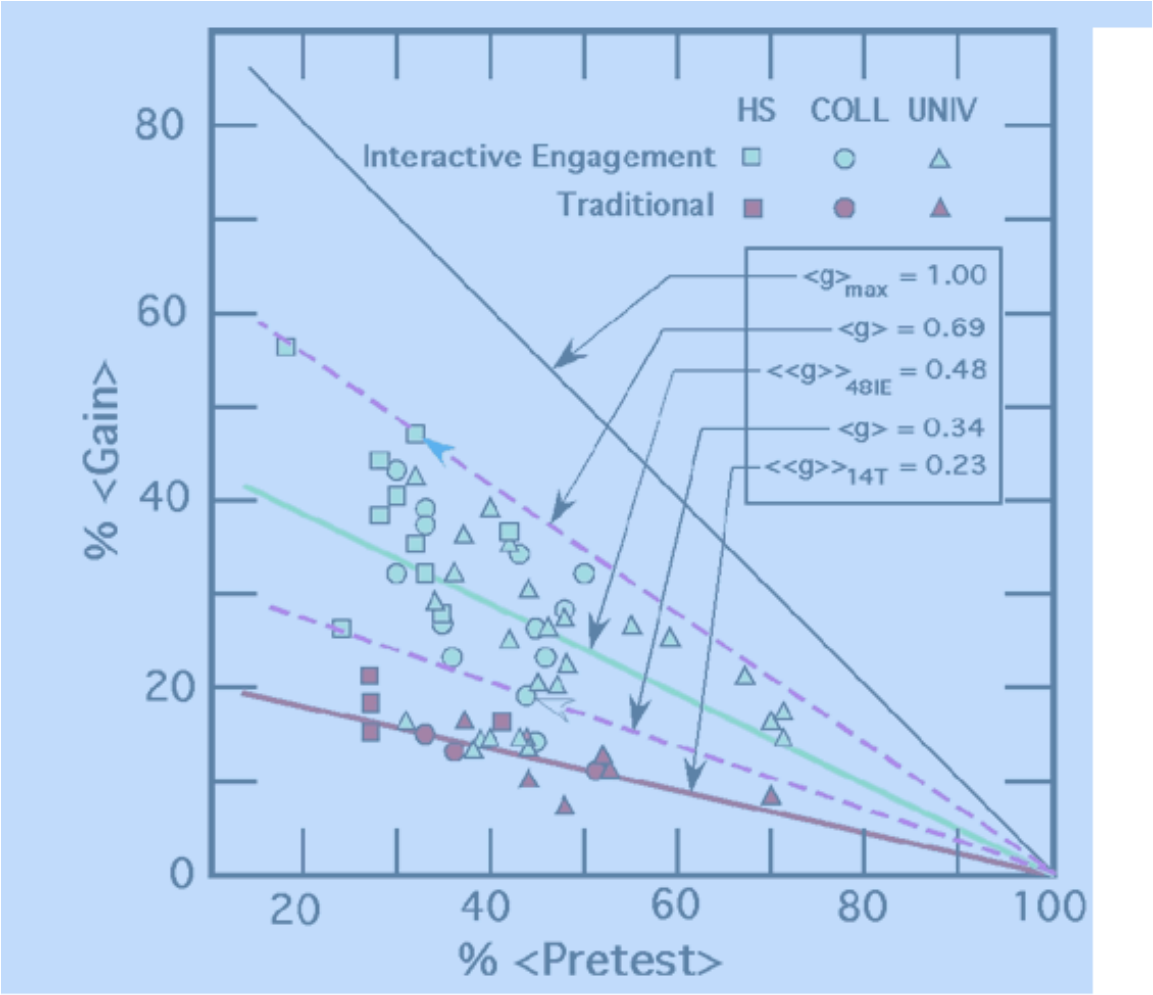
University of Windsor and Oakland University: First Annual Conference on Teaching & Learning, 2007.

ALTERNATIVES TO BLAMING THE STUDENTS:
Eleven Pedagogical Frameworks for Increasing Student Achievement, Retention & Equity, Especially in University Science Courses

Craig E. Nelson
Indiana University [Emeritus]

[OPENING CASES: Calculus, Harvard, Etc.]

EXAMPLE: HAKE'S FIGURE FOR INTRODUCTORY PHYSICS



Y Axis: %<Gain> = %<posttest> – %<pretest>
Lines: Normalized gain = % of maximum possible gain
= (%<posttest>–%<pretest>) / (100 – %<pretest>)
From: Hake, R. R. 2002. Lessons From the Physics-Education-Reform Effort. Ecology and Society [was Conservation Biology] 5(2):28 [online] http://www.ecologyandsociety.org/vol5/iss2/art28/

GROUP ONE: THE LARGEST, WELL-ESTABLISHED EFFECT SIZE

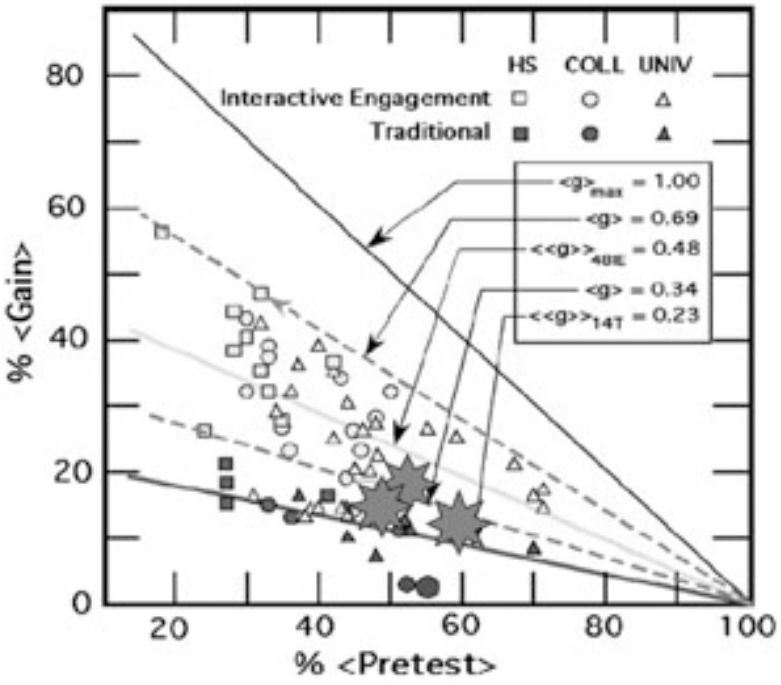
1. ACTIVE LEARNING: *How to double or triple learning while increasing equity and retention.*
= Why straight lecturing is so ineffective as to be essentially immoral.

A) Discipline based pre/post tests allow us to compare alternative and traditional pedagogies.

• **Hake**, Richard R. 2002. Lessons From the Physics-Education-Reform Effort. *Ecology and Society* [was *Conservation Biology*] 5(2):28 http://www.ecologyandsociety.org/vol5/iss2/art28/

• Crouch, Catherine H. and E**. Mazur**. 2001. Peer Instruction: Ten Years of Experience and Results *Am. J. Phys.*, 69, 970-977. At: http://mazur-www.harvard.edu/education/educationmenu.php

• **Sundberg**, Marshall D. 2003. Strategies to Help Students Change Naive Alternative Conceptions about Evolution and Natural Selection. *Reports of the National Center for Science Education* 23(2) http://www.ncseweb.org/newsletter.asp?curiss=38 *Figure. Data from [this biology] study superimposed on physics data reported by Hake (2002) demonstrating efficacy of "interactive engagement" over traditional lecture/laboratory.* ***Three large "stars" represent experimental [i.e. Integrative/Investigative]course from present study. Two large solid circles [just above axis near 50% pre-test] represent the TWO BEST sections of [17] traditional control courses:***



B) Treisman's Classic Work:

• **Treisman**, [P.] U. 1992. Studying Students Studying Calculus: A Look at the Lives of Minority Mathematics Students in College. *College Mathematics Journal* 23: 362-372. http://math.sfsu.edu/hsu/workshops/treisman.html

• Fullilove, R. E. and P. U. Treisman. 1990. Mathematics Achievement Among African American Undergraduates at the University of California, Berkeley: An Evaluation of the Mathematics Workshop Program. *Journal of Negro Education* 59(3): 463-478.

• Treisman's Model: http://www.math.uiuc.edu/MeritWorkshop/uriModel.html Applications: Math Education Database, Workshop Calculus Problems, Workshop TA Handbook etc.: http://betterfilecabinet.com/Merit Workshop, U. IL. http://www.math.uiuc.edu/MeritWorkshop/merit-introduction.html Project Excel, Northeastern U., http://www.math.neu.edu/WWW_math/Undergrad/excel.html
Math Excel, U. Ky: http://www.ms.uky.edu/~freeman/mathexcel.html

C) Very selected additional references:

• Angelo, T. A. and K. P. Cross. 1993. Example 4. pp. 69-72 in *Classroom Assessment Techniques*. 2nd edit. Jossey Bass. *"for the first time in nearly 30 years of…calculus he did not fail single student"*

• Jacobs, D.C. 2000/Web. *An alternative approach to general chemistry: Addressing the needs of at-risk* students with cooperative learning strategies. http://gallery.carnegiefoundation.org/djacobs/index2.htm At risk: 50% fewer made D/F in general chemistry, twice as many made A or B. Retention of at-risk students increased 50% in subsequent organic chemistry and sophomore biology courses and 50% more majored in science.

• Smith, Karl A, Sherri D Sheppard, David W Johnson, Roger T Johnson 2005. Pedagogies of Engagement: Classroom-Based Practices. *Journal of Engineering Education*.2005: 87-101. GREAT REVIEW
http://www.asee.org/about/publications/jee/upload/SamplePages_87-101.pdf

• Springer, L., M. E. Stanne & S. S. Donovan. 1997. *Effects Of Small-Group Learning On Undergraduates In Science, Mathematics, Engineering And Technology, A Meta-Analysis*. National Institute for Science Education, University of Wisconsin. 608/263-4214 [average effect size "would move a student from the 50th percentile to the 70th"]
http://www.wcer.wisc.edu/nise/CL1/CL/resource/scismet.htm

D) APPLYING IN YOUR CLASSES

1. *Preparation: Need Essentially ALL Students Prepared.*
General Knowledge, In-Class Reading or Lecture, Worksheet, Quiz…
Worksheets & Red Pens

2. *Cognitive Focus: On Same Topic and Important Focus*
EXPERT Question or Worksheet … [NOT "Any Questions?"]

3. *Social System* (Groups & Roles). Every Student Participating Constructively
Write-Pair-Share For Short Times.
Two-Minutes & Social Roles …
Teacher Formed Groups for Longer
Group Responsible For All Participating

How Do You Or Could You Make Each Of These Aspects Work In Your Classes?

GROUP TWO: LARGE-SCALE, STRUCTURAL & INTELLECTUAL INTERVENTIONS:

We too often leave the core frameworks of our fields tacit and thus invisible.

2. ACADEMIC AND DISCIPLINARY DISCOURSE:

A) Examples and Application

How can you have brighter and harder working students using only on hour of class time?
Essay exams, multiple-choice exams, lab reports & papers
Note: Rubrics, Criteria, etc. must be taught comparatively, not just explained

How Do You Or Could You Use These Ideas In Your Classes?

B) Key Applications

• **RUBRICS:** Dannelle D. Stevens and Antonia J. Levi. 2004. *Introduction To Rubrics: An Assessment Tool To Save Grading Time, Convey Effective Feedback and Promote Student Learning*. Stylus. *OR* Barbara E. F. Walvoord & Virginia J. Anderson. 1998. *Effective grading: A tool for learning and assessment.* Jossey-Bass

• ***Calibrated Peer Review*** (CPR)™ "is a Web-based program that enables frequent writing assignments even in large classes with limited instructional resources. In fact, CPR can reduce the time an instructor now spends reading and assessing student writing." Developed for science with $$ from NSF & Howard Hughes. http://cpr.molsci.ucla.edu/

• Also See: Getting Started [Handout]

C) References

• Bruffee, K.A. 1984. Collaborative learning and the "conversation of mankind." *College English* 46 (7): 635-652.

• Gregory G. Colomb. 1988. *Disciplinary Secrets And The Apprentice Writer*. Institute for Critical Thinking, Montclair State College.

• Craig E. Nelson. 1996. Student Diversity Requires Different Approaches to College Teaching, Even in Math and Science. *American Behavioral Scientist* 40(2):165-175. http://mypage.iu.edu/~nelson1/96_StudentDiversity.pdf

• Rose, M. 1989. *Lives On The Boundary: A Moving Account Of The Struggles And Achievements of America's Underclass.* Penguin Books. [Chapters 7 & 8 are **Essential.]**

3. TRANSFORMATIONS: PIAGET AND MORE

A) Piaget: From Concrete to Formal Operations

A major limitation for 50% or more of students in intro courses that require quantitative or experimental reasoning.

Example: *Permutations:* List names: 5 men and 5 women. How many (2 sex) dance couples can these 10 form?
Matrix as support. [Punnett square]

Example: *Ratios:* Area as L x W; Area as unit squares, irregular figures and approximation [→ calculus]

B) Beyond Piaget: Hidden Transformations Generally. Several kinds: One Example:

Example: *Concept (words) <--> Equation <--> Graph*

Rigor: Should come to univ knowing this? Baby-students? Or Teach Appropriately and Effectively?

C) Selected Sources

• Grossman, R.W. (2005) Discovering hidden transformations: Making science and other courses more learnable, College Teaching, Winter, Vol 53, Nu 1, pp 33-40. <http://www.kzoo.edu/psych/rg_Hidden.pdf>

• Arons, A. 1976. "Cultivating the Capacity for Formal Reasoning: Objectives and procedures in an Introductory Physical Science Course," *American Journal of Physics* 44 (9) 834-838.

• Arons, A. B. 1996. *Teaching Introductory Physics*. John Wiley & Sons. [Important for all quantitative disciplines.]

• Herron, J. D. 1975. Piaget for Chemists: Explaining What "Good" Students Cannot Understand. *Journal Chemical Education* 52:146-150. *[Search J. Chem. Ed. For subsequent papers too.]*

• Herron, J.D. 1978. Piaget in the classroom: Guidelines for applications. *Journal Chemical Education*, 55(3),165-170.

• Lawson, A. and Worsnop, W. 1992**.** "Learning About Evolution and Rejecting a Belief in Special Creation: Effects of Reflective Reasoning Skill, Prior Knowledge, Prior Belief and Religious Commitment," *Journal of Research in Science Teaching,* V21, No2, 143-166.

• Lawson, A. et al. 2000. "What Kinds of Scientific Concepts Exist? Concept Construction and Intellectual Development in College Biology," *Journal of Research in Science Teaching,* V37, No9, 996-1018.

4. CRITICAL THINKING AND COGNITIVE AND HOLISTIC DEVELOPMENT.

Holistic = Cognitive, ethical, sense of self and others, etc.

A) Idea: Cognitive Development & Critical Thinking. Nuclear Power as an Example:

SGT FRIDAY
Facts
One Authority Has The Truth
[Nuclear Power Either a) Is Really Safe or b) Should Be Totally Banned]
I
I <----- UNCERTAINTY
I
BASKIN ROBBINS
Opinions
Each Person's Views are Right For Her
[Nuclear Power: Why Argue? Just Respect Each Other!]
I
I <----- COMPARISONS & CRITERIA
I
TEACHERS' GAMES
Making Arguments
Let's Really Understand Everyone's Arguments & Frameworks
[Nuclear Power: Environmentalists Argue That …. Whereas …]
I
I <----- CONSEQUENCES & VALUES FRAME
| ARGUMENTS
I
OWNED GAMES
Contextual Decisions
Some Frameworks / Combinations Are More Appropriate For Particular Contexts
[Nuclear Power: Safe Enough for Some Uses (Submarines) But Not for Others (Urban Power-Plants) Because …]

B) A Key Pedagogical Example: Science-Focused Controversial Issues: Evolution, Creation or Both?

Nelson, C.E. 2000. Effective strategies for teaching evolution and other controversial subjects. Pp 19- 50 in: *The Creation Controversy and the Science Classroom***.** National Science Teachers Association. http://mypage.iu.edu/~nelson1/00_EffStrategiesEv.pdf

Nelson, C.E. 2005. How Can We Help Students Really Understand Evolution? *BioScience* 55:923. http://www.aibs.org/bioscience-editorials/editorial_2005_11.html See also: Nelson's Response…*BioScience* 56:286

Nickels, M.N. and C.E. Nelson. 2005. Beware of nuts and bolts: Putting evolution back into the teaching of classification. *American Biology Teacher* 67:289-295. http://mypage.iu.edu/~nelson1/05_Nic_&_N_Nuts Bolts.pdf

Alters, B.J. and C.E. Nelson. 2002. Teaching evolution in college. *Evolution* 56:1891-1901. http://mypage.iu.edu/~nelson1/02_A&NTchngEvHiEd.pdf

Nelson, C.E. and M. K. Nickels. 2001**.** Using humans as a central example in teaching undergraduate biology labs. *Tested Studies for Laboratory Teaching* 22:332-365. Association for Biology Laboratory Education. http://mypage.iu.edu/~nelson1/0 1_N&N_UsingHumans.pdf

Nelson, C.E., M.K. Nickels and Jean Beard. 1998. The nature of science as a foundation for teaching science: Evolution as a case study. Chapter 20 (pp. 315-328) in: W.F. McComas, Ed. *The Nature of Science in Science Education*. Kluwer Academic Publ. http://mypage.iu.edu/~nelson1/98_NNB_NOS_CaseSt.pdf

Nelson, C.E. 1986. "Creation, evolution, or both? A multiple model approach." Ch. 9 *In* R.W. Hanson, Ed., *Science and creation: geological, theological, and educational perspectives***.** Macmillian. http://mypage.iu.edu/~nelson1/86_SciCreat.pdf

Evolution and Nature of Science **Web-site** provides teacher-tested lessons and other resources for high-school and college teachers. http://www.indiana.edu/~ensiweb/

C) Another Key Pedagogical Example: Do Texts Have a Fixed Meaning?

• **Levinson**, S. 1985. On interpretation: The adultery clause of the Ten Commandments. *Southern California Law Review* 56:719-725. [Goal: Help students understand that the meaning of texts is socially constructed.]

• Nelson, C.E. 2001. . "Why Should You Publish Your Best Teaching Ideas?" *National Teaching and Learning Forum* 10(2):10-11. http://sunflower.bio.indiana.edu/~cnelson/01_4_WhyPublish.pdf [Using Levinson's case with freshmen.]

D) My Guide to Developmental Constructivist Pedagogy

• Nelson, C.E. 1999. On the persistence of unicorns: The tradeoff between content and critical thinking revisited. *In* B.A. Pescosolido and R. Aminzade, Eds., *The Social Worlds of Higher Education: Handbook for Teaching in a New Century*. Pine Forge Press. http://mypage.iu.edu/~nelson1/99_PersistenceUnic.pdf

E) Perry's Classic Study

• **Perry,** Wm. G. Jr. [1970] 1998. *Forms of Intellectual and Ethical Development in the College Years, A Scheme.* New introduction by Lee Knefelkamp. Jossey-Bass. *[Said by some to be most influential single book on higher education written in the last 50 years.].*

E) Review

• Hofer, B. & P. Pintrich. 1997. The development of epistemological theories: Beliefs about knowledge and knowing and their relation to learning. Review of Educational Research 67: 88-140. [Concisely compares Perry, Belenky et al., Baxter Magolda, King & Kitchener, Kuhn, and Schommer]

F) Landmark Studies [There are hundreds of articles on applying developmental frameworks in college classes]

• Baxter Magolda, M. 2001. *Making Their Own Way: Narratives for Transforming Higher Education to Promote Self-Development*. Stylus.

• Belenky, M., B. Clinchy, N. Goldberger, & J. Tarule. 1986. *Women's Ways of Knowing*. Basic Books.

• Bennett., M. J. 1986. Towards Ethnorelativism: A Developmental Model of Intercultural Sensitivity. Pp. 27-69 in Michael Paige (Ed.) *Cross-Cultural Orientation***.** University Press of America.

• Kegan. Robert. 1994. *In Over Our Heads: The Mental Demands of Modern Life*. Harvard University Press.

GROUP THREE: FINE-SCALE BARRIERS: REASONS WHY ACTIVE LEARNING MATTERS SO MUCH

5. LEARNING THEORY & LEARNING SCIENCES. *Why straight lecture doesn't work.* EX: Guppy Effect.

• Commission on Behavioral and Social Sciences and Education (***CBASSE***). **2000.** *How People Learn: Brain, Mind, Experience, and School: Expanded Edition***.** National Academy Press. Read online and print free or buy at http://fermat.nap.edu/books/0309070368/html/ [REPLACED: **Bransford,** J. D., Brown, A. L. & Cocking, R. R., Editors. 1999. *How People Learn: Brain, Mind, Experience, and School.*] ADDITIONAL APPLICATIONS: M. Suzanne Donovan and John D. Bransford, editors. **2005**. [Three titles:] [1] *How Students Learn: Mathematics in the Classroom.* [2] *How Students Learn: Science in the Classroom.* [3] *How Students Learn: History in the Classroom* . Committee on How People Learn: A Targeted Report for Teachers. National Research Council. National Academy Press ["… how the principles of learning can be applied in science [or math or history] at three levels: elementary, middle, and high school. Leading educators explain in detail how they developed successful curricula and teaching approaches…"] ***Read online and print free*** or buy at http://www.nap.edu/catalog/10126.html

6. MISCONCEPTIONS & ALTERNATIVE CONCEPTIONS: *Why students frequently do not understand a concept even when you explain it clearly and repeatedly.*

• Duit, Reinders. 2007. Bibliography – STCSE: Students' and teachers' conceptions and science education. Online www.ipn.uni-kiel.de/aktuell/stcse/stcse.html *[Approximately **7,000** studies and reviews; Downloadable, searchable.]*

• Novak, Joseph et al. *Meaningful Learning Research Group Home Page.* UC Santa. Cruz. Science focused. Misconceptions, concept maps, etc. Downloadable articles and mapping tools. http://www2.ucsc.edu/mlrg/mlrghome.html

• Shaughnessy, M. 1977. *Errors and Expectations*. Oxford University Press.

7**. LEARNING STYLES.** *Heuristic: Helpful insights for faculty and students.* **[**Careful: Psychological validity of many not acceptable for many research purposes.]

• M. D. Svinicki, M.D. and N. M. Dixon. 1987. The Kolb Model Modified for Classroom Activities. *College Teaching* 35:141-146. Essential Reading

• Learning Styles Assessment Instruments Resource Page. Descriptions and sources for about 20 instruments in groups; brief bibliography. **http://www.brevard.edu/fyc/resources/Learningstyles.htm**

8. STEREOTYPE THREAT

• Steele, Claude M. 1997. A Threat In The Air: How Stereotypes Shape Intellectual Identity And Performance. *American Psychologist* June 1997: 613-629.

• Steele, C. M. 1999. Thin Ice: 'Stereotype Threat' and Black College Students. *Atlantic Monthly* Aug.1999:44-54. http://www.theatlantic.com/issues/99aug/9908stereotype.htm [subscribers] http://www2.newton.mec.edu/~gary_shiffman/Thin%20Ice

• Aronson, J., Lustina, M., Keough, K., Brown, J. L., & Steele, C. M. (1999). When White men can't do math: Necessary and sufficient factors in stereotype threat. *Journal of Experimental Social Psychology*, 35, 29-46. (For An Application Showing That Whites Can Experience Stereotype Threat)

• Cohen, G. L. and C. M. Steele. 2002. A Barrier of Mistrust: How Negative Stereotypes Affect Cross-Race Mentoring. Pp 303-327 in *Improving Academic Achievement.* Elsevier.

9. SOCIAL-CLASS, GENDER & RELATED ASSUMPTIONS IN GRADING, DEADLINES ETC.

• Craig E. Nelson. 1996. Student Diversity Requires Different Approaches to College Teaching, Even in Math and Science. *American Behavioral Scientist* 40(2):165-175. http://mypage.iu.edu/~nelson1/96_StudentDiversity.pdf

• Giacomini, M., P. Roze-Koker and F. Pepitone-Arreola-Rockwell. 1986. Gender bias In Human anatomy Textbook Illustrations. *Pyschology Of Women Quarterly* 10:413-420.

• Lorenzo, Mercedes, Catherine H. Crouch and Eric Mazur. 2006. Reducing the gender gap in the physics classroom. *American. J. Physics*., 74, 118-122. [Active engagement including peer instruction narrows gap.]

• McIntosh, Peggy. 1988. White Privilege: Unpacking the Invisible Knapsack. *Reprinted from the Winter 1990 issue of Independent School.* http://seamonkey.ed.asu.edu/~mcisaac/emc598ge/Unpacking.html [available in several versions--try Google if needed). Excerpted from her *White Privilege and Male Privilege: A Personal Account of Coming To See Correspondences through Work in Women's Studies"* Wellesley College Center for Research on Women.

• Caryn McTighe Musil, Editor. 2001. *Gender, Science, and the Undergraduate Curriculum: Building Two-Way Streets*. AACU. ["How can things be done differently to increase the numbers of women who study science, math and engineering?" and "How will the new scholarship about women and gender alter science itself and how science is understood both within its own disciplines and beyond?"]

• NSF. 2000. *A Description and Analysis of Best Practice Finding of Programs promoting participation of underrepresented undergraduate student in Science, Mathematics, Engineering and Technology*. nsf0131. http://www.nsf.gov/pubs/2001/nsf0131/nsf0131.pdf

• Rosser, S.V**.** 1997. *Re-Engineering female Friendly Science*. Teachers College Press.

• Tobias, S. 1990. They're Not Dumb, They're Different, A New "Tier of Talent" for Science. *Change* July/Aug 1990 (Excerpted on 241-243 in D. DeZure (Ed.) 2000. *Learning From Change*. Stylus.) Longer version: S. Tobias. 1990. *They're Not Dumb, They're Different: Stalking the Second Tier.* Research Corporation. 94 pp.

10. LESS *REALLY* IS MORE

• Nelson, C.E. 2001. "What Is The Most Difficult Step We Must Take To Become Great Teachers?" *National Teaching and Learning Forum* [= *NTLF*]. 10(4): 10-11. http://mypage.iu.edu/~nelson1/01_6_MostDifficult.pdf

• Russell, I. J., W. D. Hendricson & R. J. Herbert. 1984. "Effects of lecture information density on medical student achievement." *Journal of Medical Education* 59:881-889.

• Sundberg, M. D. and M. L. Dini. 1993. Science majors vs nonmajors: Is there a difference? *Journal of College Science Teaching.* Mar/Apr 1993:299-304. [Multiple sections and instructors. Both courses taught with traditional pedagogy, but with different intensities of 'coverage.' "The most surprising, in fact shocking, result of our study was that the majors completing their course did not perform significantly better than the corresponding cohort of nonmajors." Note: Less wasn't more, without pedagogical change, but more wasn't more either--and student attitudes suffered.]

• Sundberg, M.D., M.L. Dini and E. Li. 1994. Improving student comprehension and attitudes in freshman biology by decreasing course content. *Jour. Res. Sci. Teach.* 31: 679-693.

[11. I combined Piaget and hidden transformations for quicker understanding.]