Scientific Teaching

Evidence for Change in Science Education

Jo Handelsman

Yale University

Impetus for Change in Science

- AAAS “Science for All Americans”
- NRC “How People Learn”
- NAS “From Analysis to Action”
- NRC “Bio2010”
- President Obama “Win the Future”

Reasons For Change

- Widespread scientific illiteracy

A Tiny World

Reasons For Change

- Inability of science students to engage in conceptual & analytical thinking
- Poor retention (10-20% lecture content)
- Exit of students from college science (biology majors ~60%)
- Greater loss of certain ethnic minorities (~80% for African American students)
- Long term lack of persistence of women in academic science

Scientific Teaching

- the *learning* should be active
- the *content* should capture the nature of science and the scientific endeavor
- the *teaching* should reflect the rigor, iterative nature, and spirit of discovery of science at its best
- the *students* should capture the strength of diversity

Handelsman et al., 2004 Science 304:521-522.

Scientific Teaching in Practice

Active learning
- Students must be engaged in the process of science

Assessment
- Need to determine whether learning occurs

Diversity
- Science depends on contributions from diverse people for creativity – so should teaching

Scientific Teaching in Practice

Active learning
- Students must be engaged in the process of science

Assessment
- Need to determine whether methods work, not assume they will

Diversity
- Science depends on contributions from diverse people for creativity – so should teaching

Backward Design

- Set learning goals
- Design Assessments
- Determine whether students meet learning goals

Active Learning

Fast = Rapid

Fast = R__p__d

Examples of Active Learning in the Classroom

- Think-pair-share (in lecture)
- Notecards (in lecture)
- Clickers (in lecture)
- Case studies (in lecture/discussion/lab)
- Inquiry-based experiments (in lab)
  - What would you like know about…..?
  - How would you…..?
  - Why do you think…..?

Active Learning Works

- Helman and Horswill, 2002
  - 10% increase in exam scores
- Sivan et al., 2000
  - Enhanced ability to be “self-managed learners” and critical thinking skills
- Felder , 1998
  - Students in traditional lecture course twice as likely to leave engineering and three times as likely to drop out of college entirely as those taught with active methods

Cooperative Learning Works

- Deutsch, M. 1949 Coop learning fosters:
  interdependence, achievement pressure
  higher productivity, more ideas
- Okebukola, P.A. 1984 1,025 9th graders
  Cooperative mode--intellectual achievement
  Competitive mode--practical lab skills
- Johnson, D.W. et al. 1981 -- 122 studies
  Cooperative = higher achievement
  higher order thinking
- Swisher, K. and others in the 1990s
  Cooperative learning = higher achievement
  Native Americans (Navajo, Cherokee)
  African Americans
  Female Americans

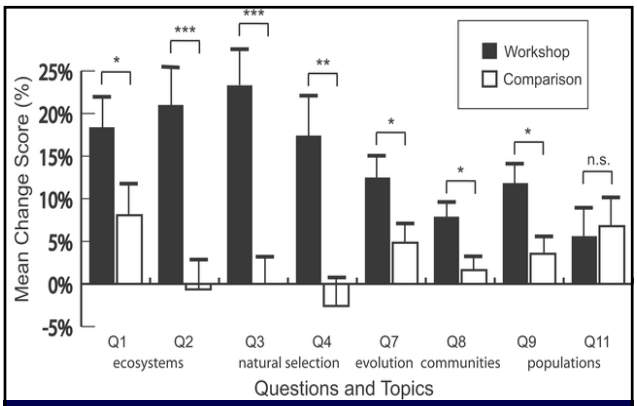
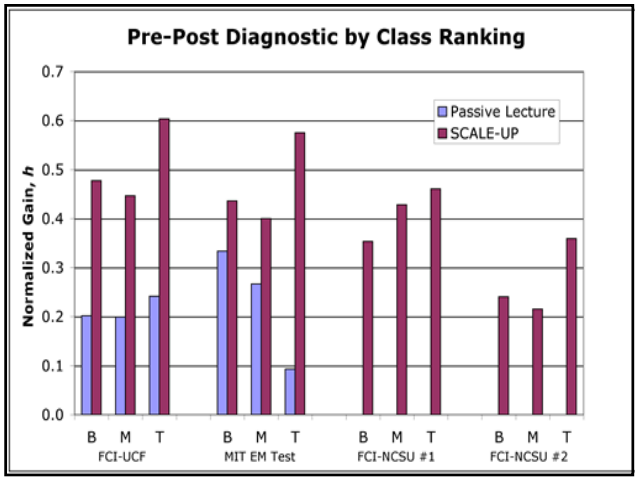


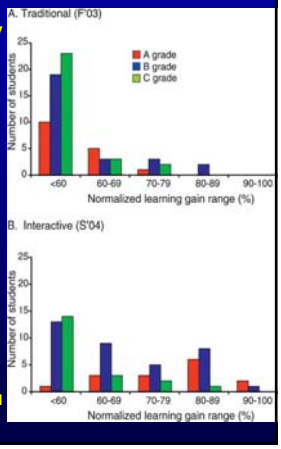
*Figure 2. Mean change scores on spring 1993 concept test, by question. Error bars represent one standard error (*p<0.05; **p< 0.01; ***p<0.001; n.s. p> 0.05).*



Active Learning in Developmental Biology at U Colorado

With "clickers"

- Learning gains increased 9%
- Increase greatest for best students
- Increase greater for women than men



From:
"Teaching More by Lecturing Less" **Jennifer K. Knight and William B. Wood**
Cell Biol Educ 4(4): 298-310 2005

Assessment and Active Learning

- Backward design
  - Decide on learning goals
  - Design assessment
  - Design content
- Assessment is learning

Learn assessment techniques

What is the freezing point of water?

http://www.youtube.com/watch?v=zbfkjp5Njs4&feature=player_detailpage

Scientific Teaching in Practice

Active learning

- Students must be engaged in the process of science

Assessment

- Need to determine whether methods work, not assume they will

Diversity

- Science depends on contributions from diverse people for creativity – so should teaching

Human diversity leads to…..

- Better academic experience *(Milem, 2001)*
- More feasible and effective solutions to problems *(Cox, 1993; McLeod, 1996)*
- Better, more defensible decisions *(Nemeth, 1985; 1995)*
- More innovation in teams *(Kanter, 1983)*
- Best teams in science and theater *(Science, 2005)*

Cognitive and Learning Styles

Cognitive style

Process of thinking, perceiving, and remembering (McFadden, 1986)

Cognitive and Learning Styles

Cognitive style

Process of thinking, perceiving, and remembering (McFadden, 1986)

Learning Style

Preferred way to learn (Gregorc, 1979)

Behaviors associated with learning (Kocinski, 1984)

Cognitive Style Assessment

http://www.berghuis.co.nz/abiator/lsi/lsiframe.html

http://www.ncsu.edu/felder-public/ILSpage.html

Diversity in the Classroom

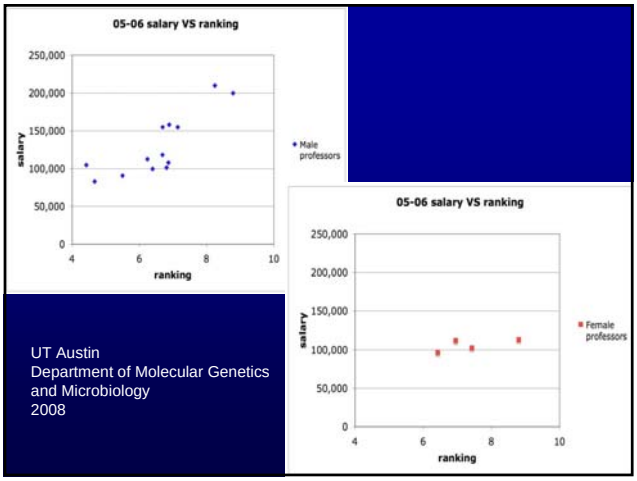
- Accommodate diverse cognitive and learning styles with diverse methods
- Examine unconscious bias to minimize its impacts

Our claim of objectivity

- "We're scientists – we evaluate the data dispassionately
- "We only hire the best"
- "I know it when I see it"
- More rigor?

Award (since 2000)	# to women	# to men	% to women
AAAS Newcomb Cleveland Prize	0	13	0
Lasker Foundation	2	35	5
Nobel Prize in Physiology or Medicine	4	23	15
Presidential Medal of Science	9	56	16

Handelsman and Grymes, 2008



UT Austin
Department of Molecular Genetics and Microbiology
2008

A substantial body of evidence establishes that most people—men and women—hold implicit biases.

Decades of cognitive psychology research shows that

- **most of us intend to be fair**
- **most of us carry unconscious prejudices**
- **these biases influence our evaluations of people and their work**

Research on Bias

- **When shown photographs of people who are the same height, evaluators overestimated the heights of male subjects and underestimated the heights of female subjects.**
- **When shown photographs of men with similar athletic ability, evaluators rated the athletic ability of African American men higher than that of white men.**
- **When asked to rate the quality of verbal skills indicated by a short text, evaluators rated the skills as lower if they were told an African American wrote the text than if a they were told a white person wrote it, and gave lower ratings when told a woman wrote it than when told a man wrote it.**

Biernat et al., 1991; Biernat and Manis, 1995

Hiring Studies

Randomized and controlled

Applications assigned male or female name

Evaluators review credentials of applicant

- Substantially more likely to hire a given applicant if there is a man's name on application
- **Same result over 40 years**

Research on Bias

- CVs of real woman assigned a male or female name, randomly, and sent to 238 academic psychologists
  - CV at time of job application
  - CV at time of early tenure decision
- Respondents more likely to hire if male name on job application
- Gender of applicant had no effect on respondents' likelihood of granting tenure

Steinpreis et al., 1999

Research on Bias

There were "cautionary comments" in margins of tenure package four times more often on those with woman's name:

"We would have to see her job talk."

"It is impossible to make such a judgment without teaching evaluations."

"I would need to see evidence that she had gotten those grants and publications on her own."

Steinpreis et al., 1999

Research on Bias

- **Linguistic analysis of letters of recommendation**
- **300 letters for successful candidates for faculty positions at major medical school**
- **Differences in language and content:**
  - **Men – "researchers" and "colleagues"**
  - **Women – "teachers" and "students"**
  - **Women – 4X more references to personal lives**
  - **Women – more "doubt raisers"**

Trix and Psenka, 2003

Research on Bias

- In every study, significant effect of gender or race of person evaluated
- NO significant effect of gender or race of person doing the evaluation

Reactions to Evidence of Bias

Not here…..

- "It's like that in Sweden, but not here."
- "It's like that at rural universities, but not urban ones."
- "It's like that at Harvard, but not at UW."
- "It's like that at UW, but not at Harvard."
- "It's like that at UW, but not at Yale."
- "It's like that in the economics department, but certainly not here in chemistry!"

Reactions to Evidence of Bias

Dismissal

- "Women and minorities are just too sensitive"
- "What's the standard deviation in line 4 of Table 3 of the 1988 study?"
- "Those social scientists are all biased and have a point to prove – with small sample sizes, you can show anything!"

37

Scientific Teaching

Keep it evolving

Use our secret weapon to advance science education

Acknowledgments

- Jenny Fredericks, Yale
- Jim Young, Yale
- Sarah Miller, U of Wisconsin
- Chris Pfund, U of Wisconsin
- Christine Pribbenow, U of Wisconsin
- Adam Fagan and Jay Labov, Natl Acad Sci
- Peter Bruns, HHMI

Howard Hughes Medical Institute
National Science Foundation