Large-Scale Pedagogical Change and Sustainability

(at a Large Research University)

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An opportunity

- Hundreds of research papers ⇒ pedagogical approaches much better than traditional lecturing. And yet traditional lecturing still dominates.
- Call to action:
  - White House PCAST 2012 report *Engage to Excel*.
  - National Academies 2012 study on *Discipline-Based Education Research*.
  - AAU 2012–17 *Undergraduate STEM Education Initiative*.
  - White House 2016 *Call to Action on Active STEM Learning.*
  - American Academy of Arts & Sciences 2017 commission and report on the *The Future of Undergraduate Education*.

Research: how students learn

- Major advances in last 10-20 years from cognitive psychology, discipline-based education research (DBER), and more recently brain science.

- New paradigm for the goal of education:

  - Learn how to think like an expert (better decisions/choices) through deliberate practice with expert (i.e., faculty) feedback.

  - Expert knowledge = facts + mental framework: deep (vs surface) structure of disciplinary knowledge, standards of evidence, discipline-specific procedures and criteria for when to apply them, self monitoring (metacognition). Rewire the brain.

On how experts are made: for example, K. A. Ericsson *et al*, *Cambridge Handbook of Expertise and Expert Behavior (2006).*

How with class of 300 students?

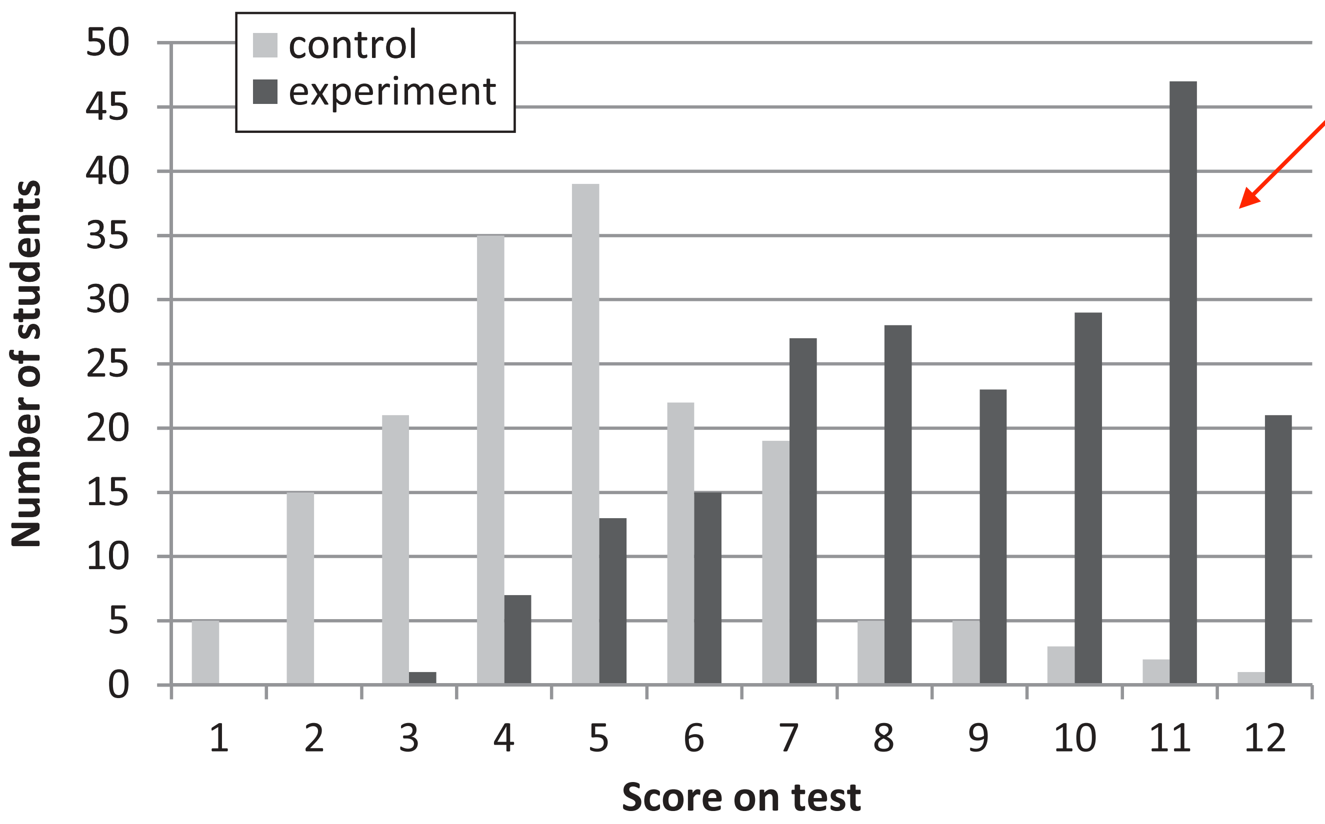
- New designs for classroom instruction (active learning):
  - Pre-class reading provides basic subject coverage (online quiz).
  - In class, no formal lecturing. Instead focus on key/difficult issues using 3-4 problems, each in 4 steps (10–15 minutes/problem):

1. Instructor briefly describes problem.
2. Students work on it and vote (clicker).
3. While instructor circulates, students discuss problem with other students, and then revote.
4. Instructor discusses what is right/wrong and why, perhaps calling on students (mini-lecture).

  - Deliberate practice = challenge students + prompt feedback, again and again, on most difficult ideas.

Research: lecturing much less effective

- Deslauriers *et al* (Science 332 (2011) 862) compare traditional physics lecture and active learning, with 270 students in each section, both in large lecture halls:

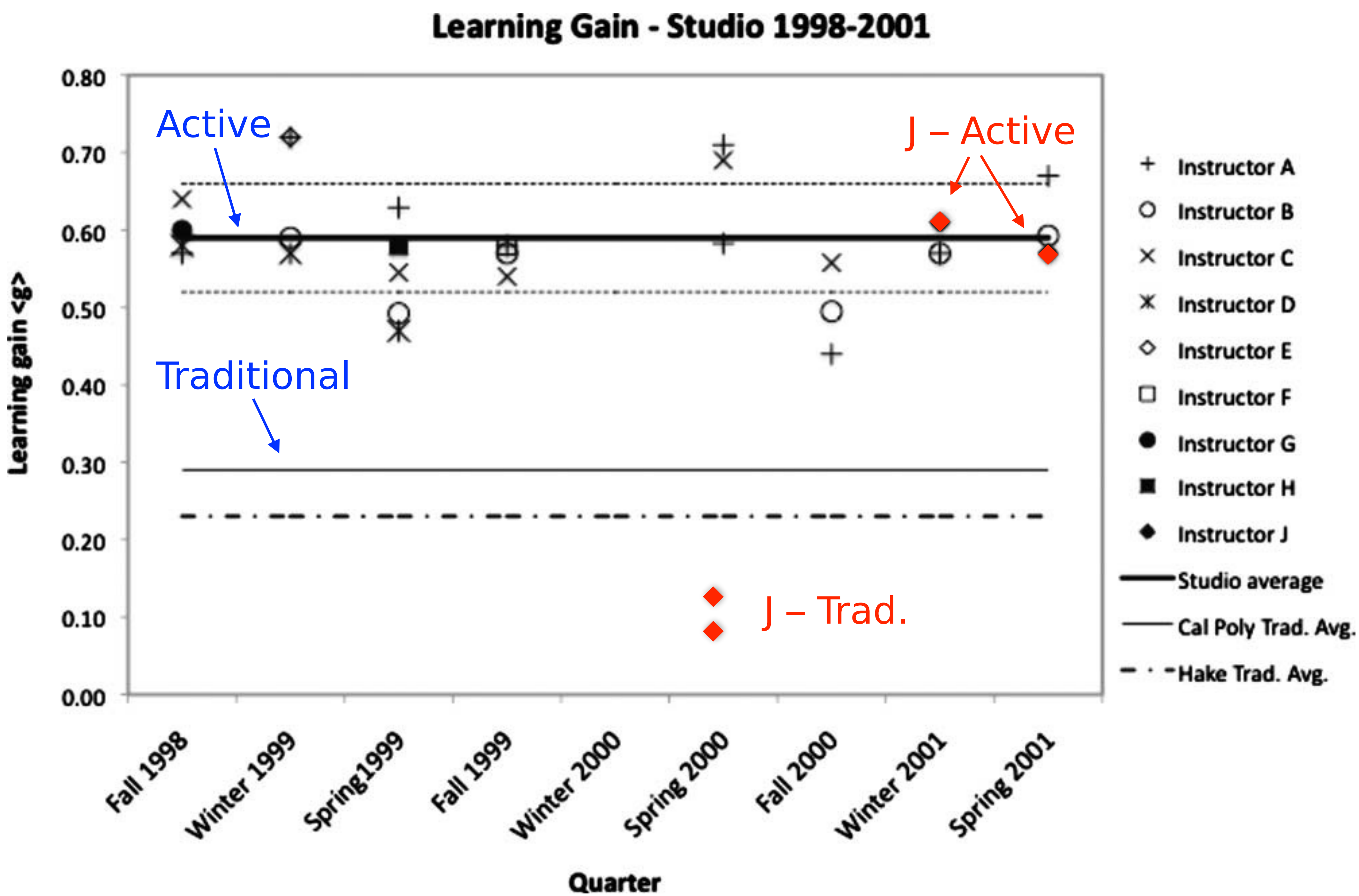


Entire grade distribution shifted up by 2.5 letter grades with active learning.

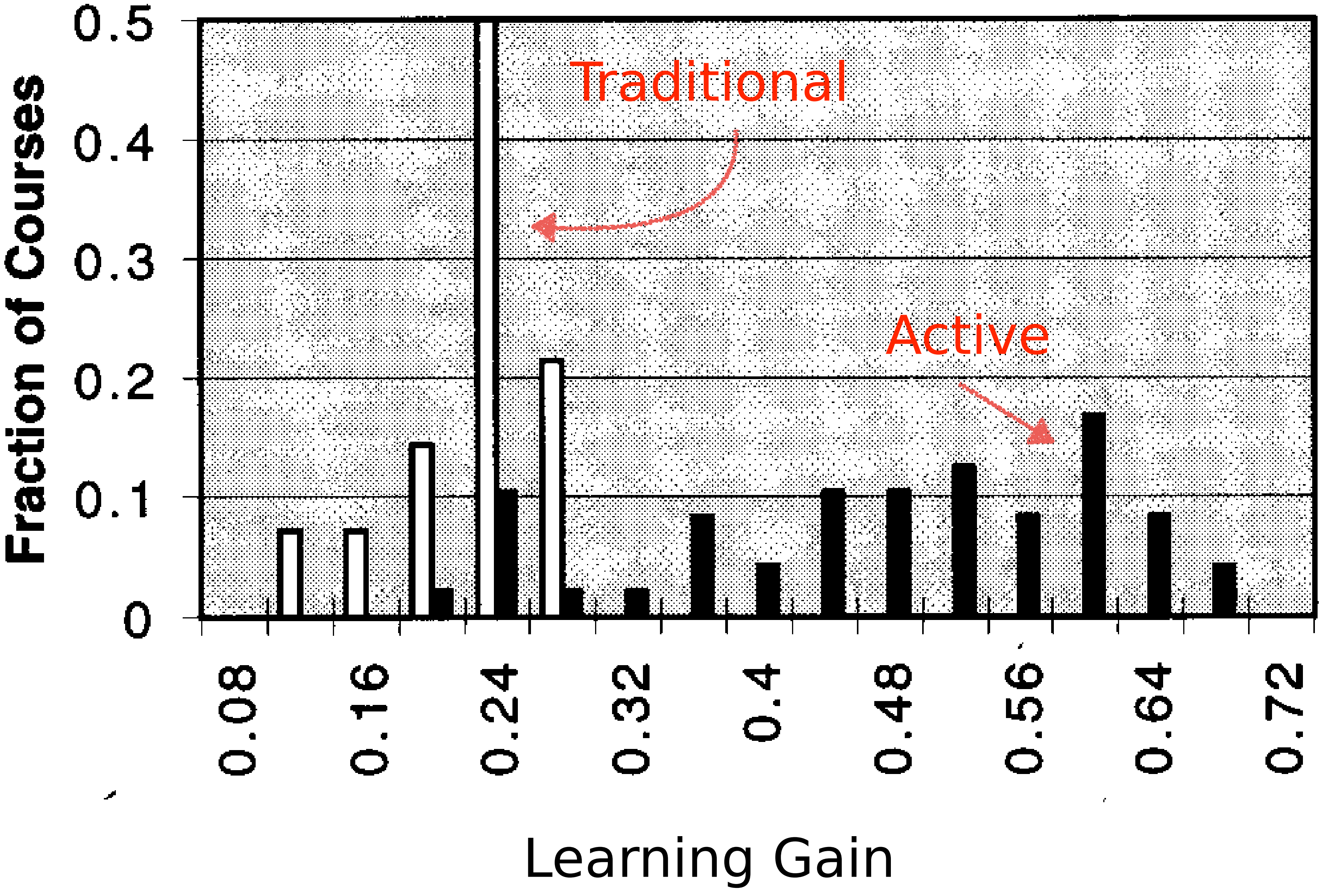
Students learning in real time! Scalable substitute for 1-on-1 tutoring?

- Clickers ⇒ new opportunity unavailable 20 yrs ago.

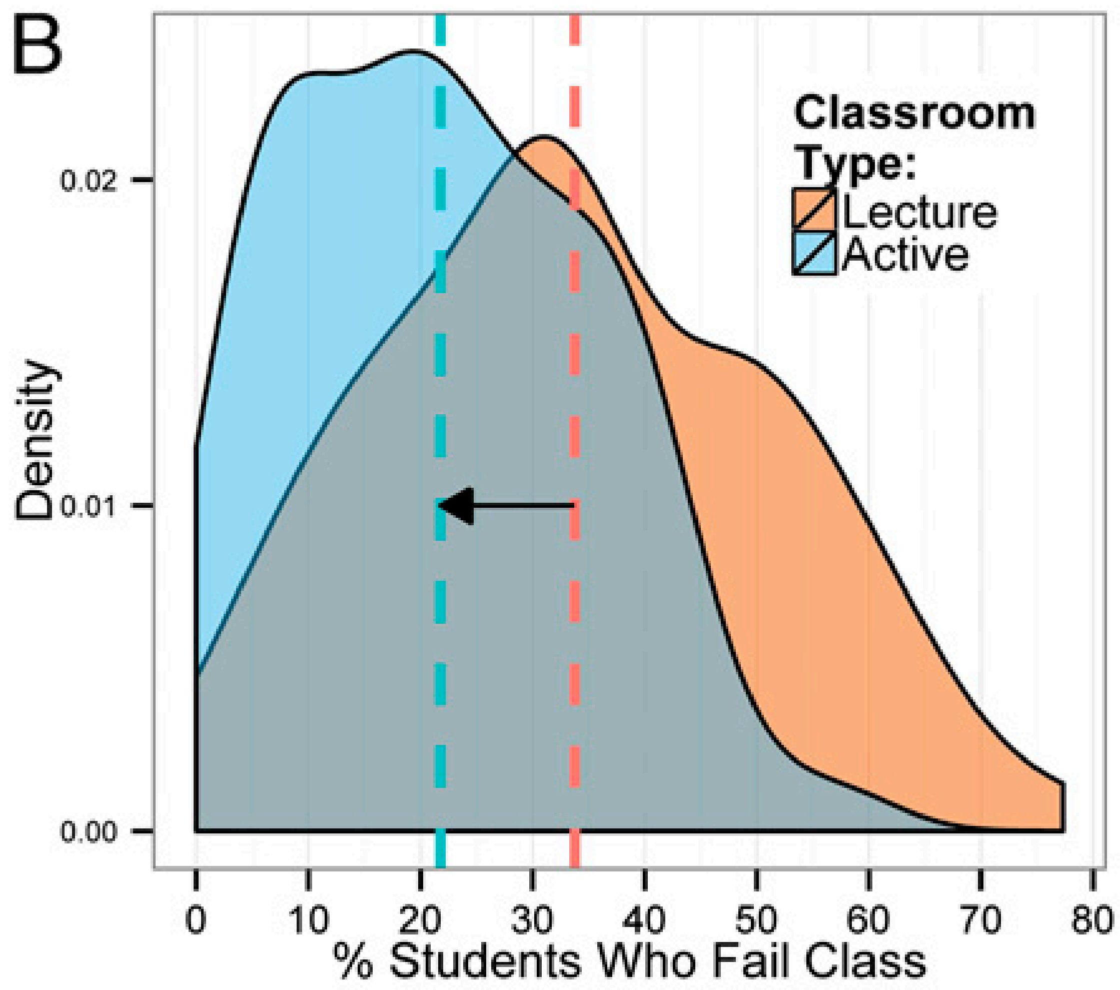
- Hoellwarth *et al* (Am. J. Phys. 79 (2011) 540) ⇒ learning gain is instructor-independent.



- Hake (Am. J. Phys. 66 (1998) 64) ⇒ similar results from 62 intro physics courses at 62 institutions, enrolling 6542 students:



- Freeman *et al* (PNAS 111 (2014) 8410) ⇒ meta-analysis of 225 education research papers (selected from 642) in eight STEM fields.

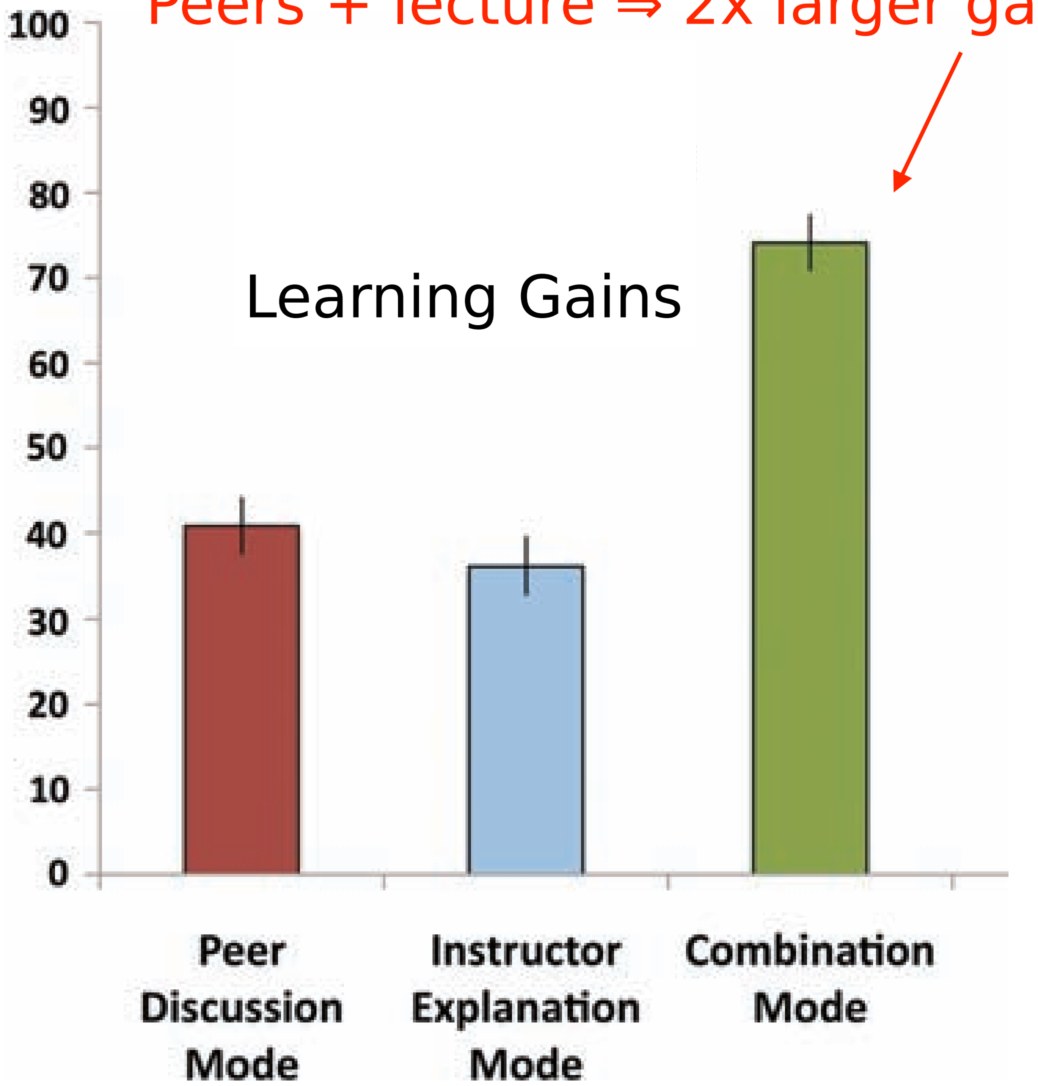


  - Active learning ⇒ 0.47σ improvement in exam or concept inventory scores.
  - Students 1.55 times more likely to fail in traditional lecture course.
  - Paper says unethical to use conventional lectures as controls.

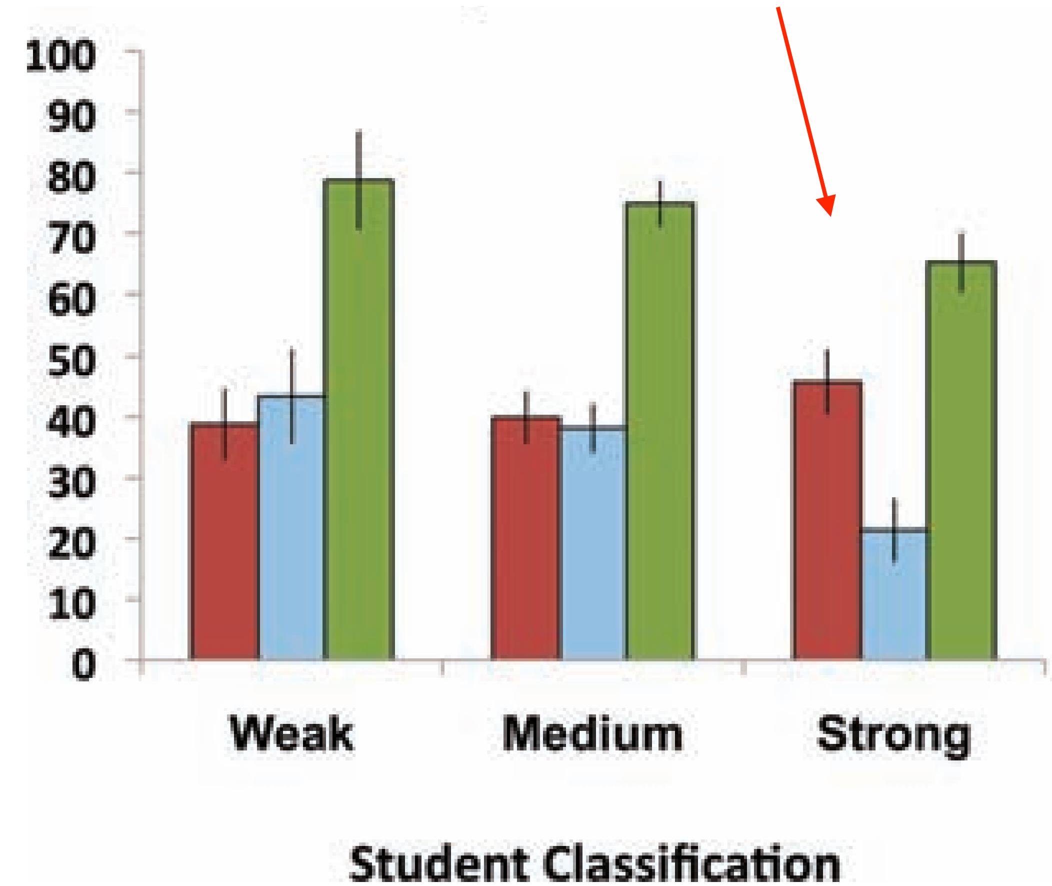
Research: lecturing* is powerful

Smith *et al* (CBE-Life Sc. Ed. 10 (2011) 55) compare peer instruction with lecturing (genetics course):

Peers + lecture ⇒ 2x larger gains.



Peers more effective than lecture, especially for strong students. Not just "transmission."



* Done at the right time.

Active Learning Initiative:

an example from Cornell

Design Assumptions/Considerations

- Goal: change teaching culture of entire faculty.
- Teaching expertise is a real thing that can be taught (and has to be learned).
- Most faculty want to teach well, but are uninformed/ skeptical about the relevant new research. Lack of time is chronic.
- Departments are critical for sustaining changes in teaching culture.
- Volunteers are far more effective than conscripts.

Competitive grants for departments

- Departmental proposal, led by chair and approved by entire faculty (vote).
  - Multi-year, multi-course, and multi-instructor team.
  - Essential for sustainability.
- Competition ⇒ departments/faculty with best ideas and strongest interest.
  - Participation optional.
  - Identify (validate) knowledgeable faculty ⇒ team leaders.
- Exclusive focus on pedagogy, not curriculum or …

- Sufficient funding for extra staff (mostly postdocs).
  - Faculty can change pedagogy without heroic sacrifice.
  - Also sufficient to attract attention of departments.
  - Up to $1M over 5 years per department.
- One-time investment for course redesign.
- Donor supported (current-use funding) — thanks to Alex and Laura Hanson!

Support for department projects

- Ongoing help/oversight from central project, beginning with pre-proposals.
  - Departments know very little or no learning science.
  - Direct involvement by dean.
- Training faculty and especially teaching postdocs/fellows to assist faculty in course redesign.
  - Reconfigure “Center for Teaching and Learning” to support multi-year, department-level projects.
- Course design.
  - Detailed learning goals ⇒ student activities.
  - Consult education experts (e.g., cwsei.ubc.ca/resources).

- Incentives for faculty.
- Designing and implementing assessment plans.
  - Tracker questions, concept inventories, student interviews, observation protocols (e.g., COPUS), faculty surveys (e.g., TPI), ...
  - Assessment results highly motivating for (all) faculty.
  - Authentic criteria for rewarding departments and individuals.
  - Education research publications (important for teaching postdocs).
- Sustainability.
  - Department dictates pedagogy; monitor with assessment metrics.
  - Embed DBER faculty, *etc.* in departments.
  - Archive materials; use to train new faculty.

Response

Round 1 (2012):

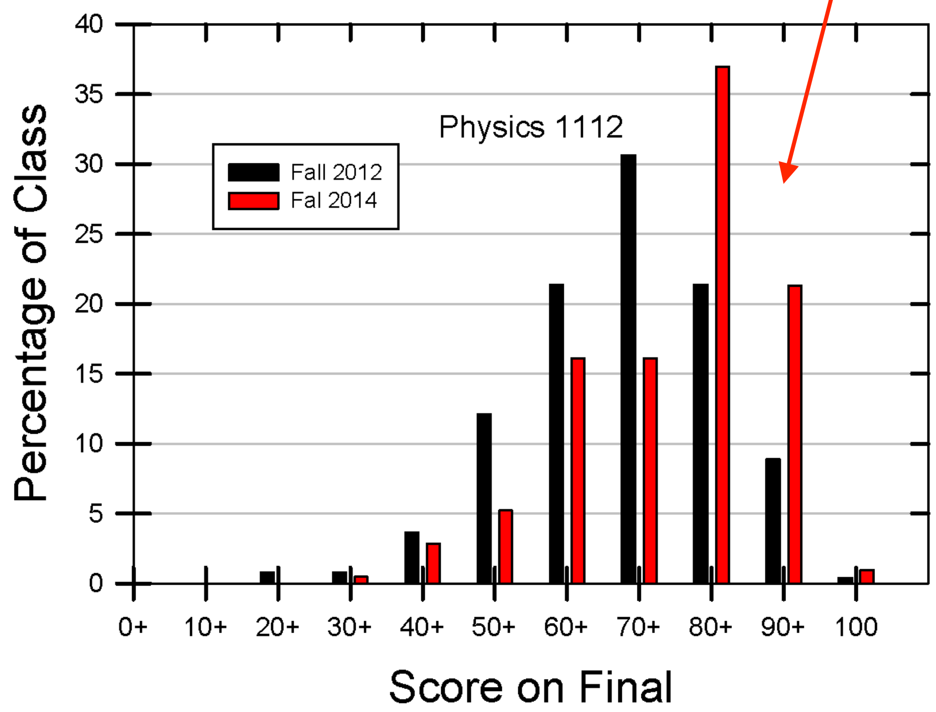
- Funded proposals in Physics and Biology (EEB, NBB).
- Grant sizes: $700K-800K over 5 yrs for teaching relief and teaching postdocs.
- 7 large intro courses affecting thousands of students.
- Faculty teams of 6–8 in each department (volunteers; all ages).

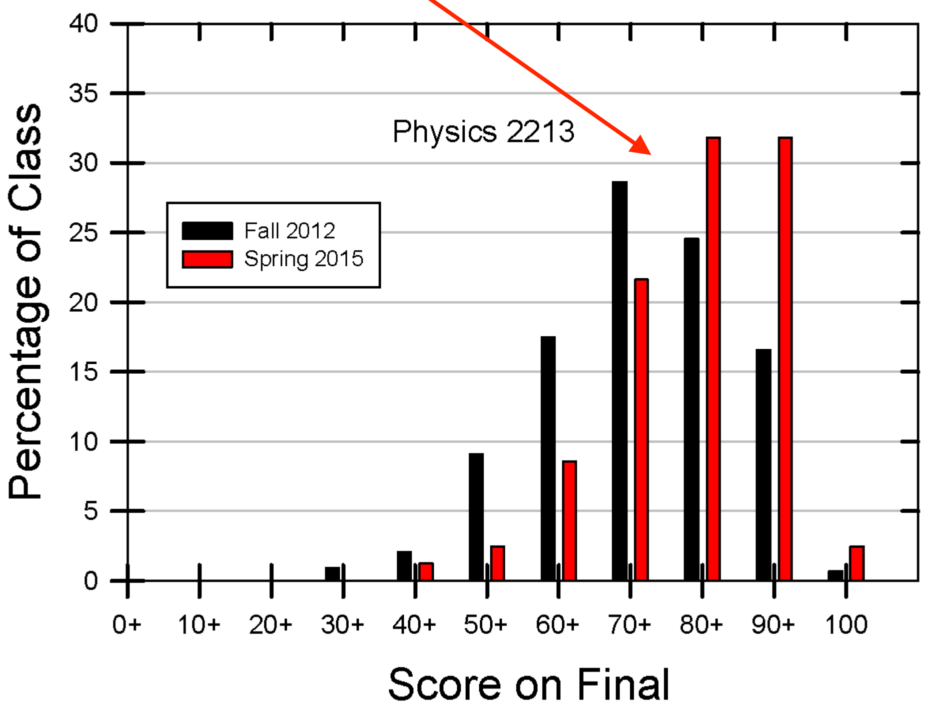
Round 2 (2017):

- Funded proposals affecting 26 courses in Anthropology, Classics, Economics, Mathematics, Music, Physics (lab), and Sociology.
- Grants range from $160K to $1M over 5 yrs, mostly spent on teaching postdocs/fellows.

Results: intro physics for engineers

Grade distribution shifted up by almost 2/3 letter grade.





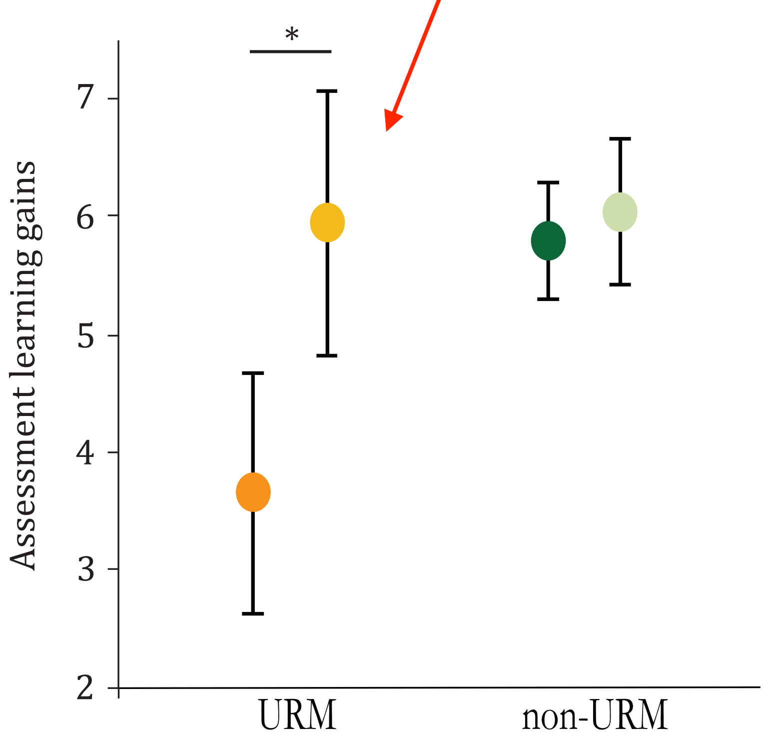
Low/marginal grades reduced from 17% to 4%.

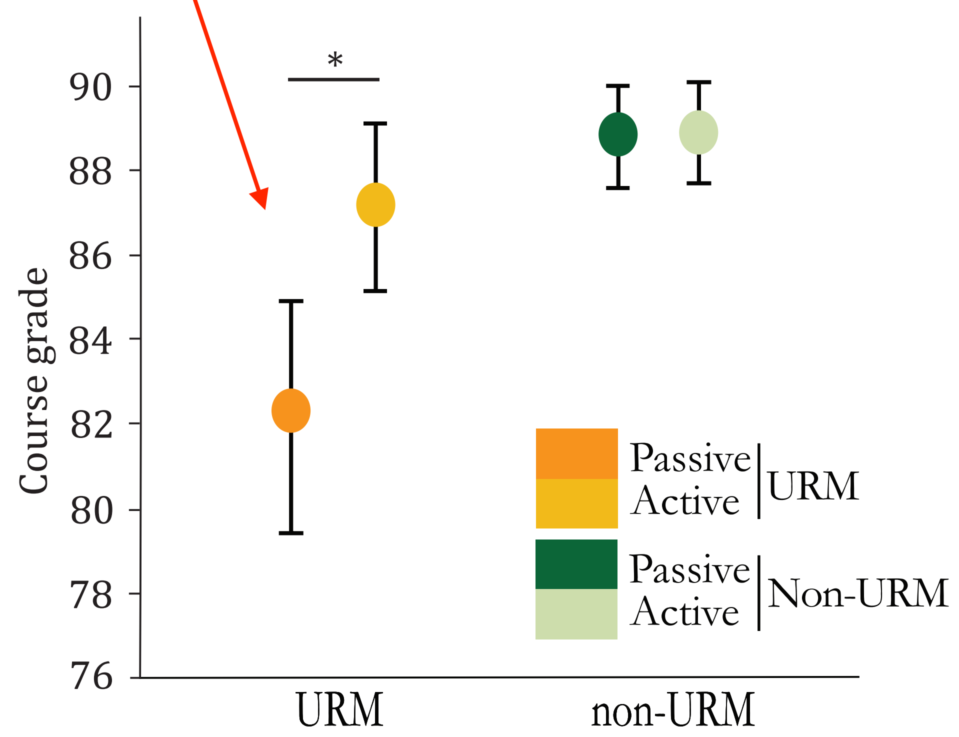
– Student evaluations scores increased to 4.1-4.6 out 5.

– Student-faculty barriers greatly reduced.

Results: intro evolutionary biology

Eliminated learning gap between URM students and others.

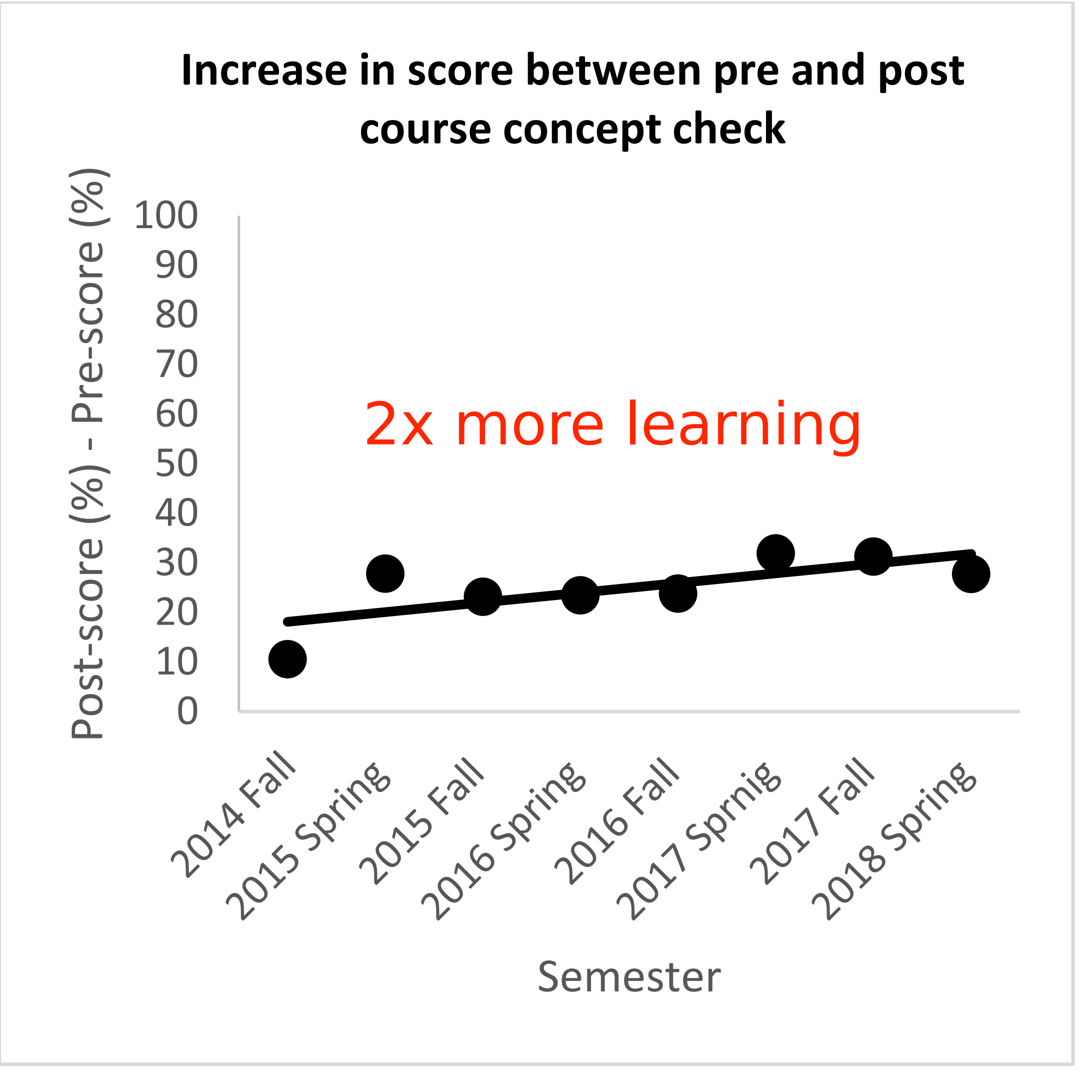


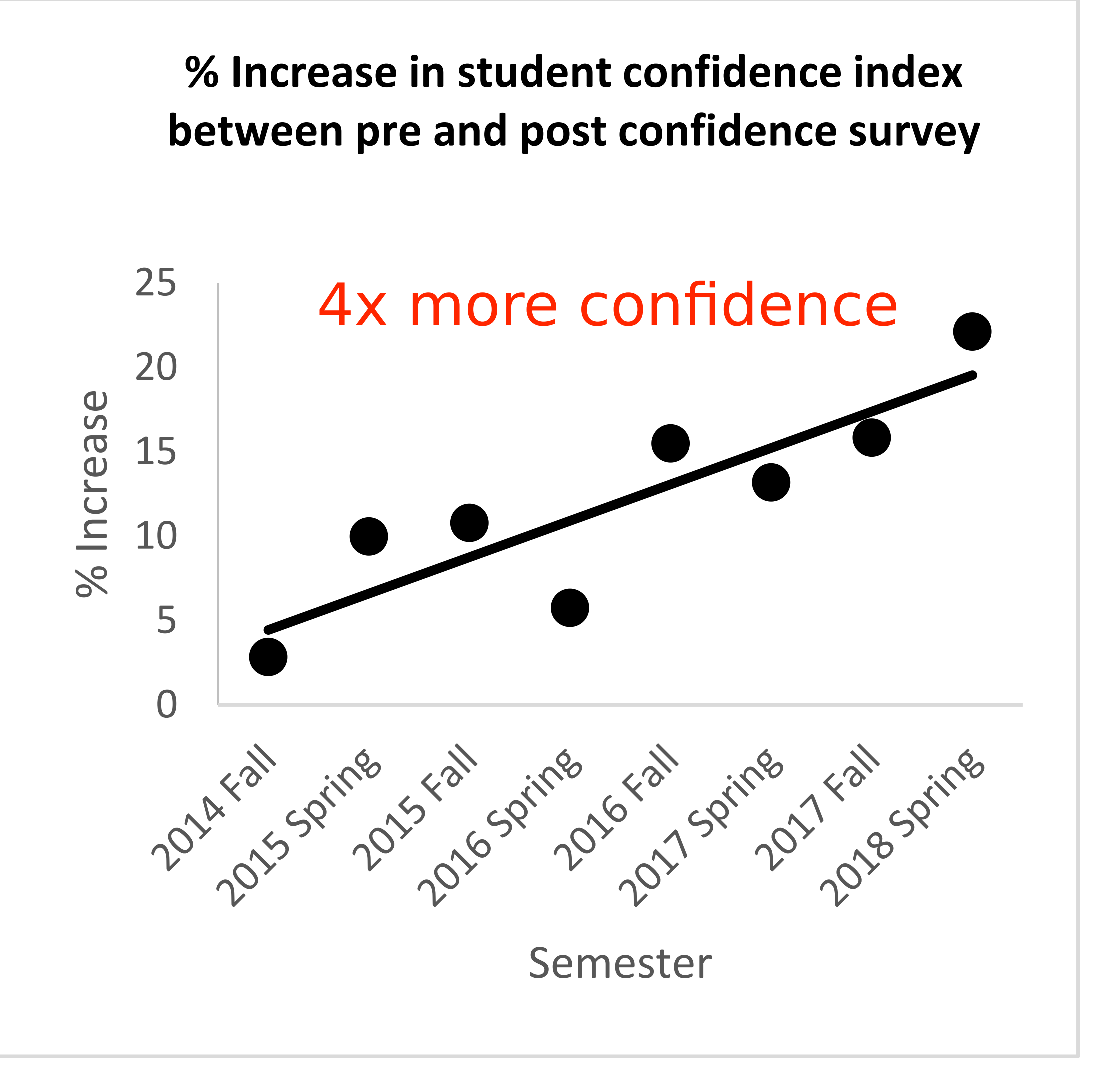


3–7x fewer low/marginal grades; self-confidence is key.

Ballen *et al*, CBE-Life Sc. Ed. 16:ar56 (2017).

Results: intro ecology/environment



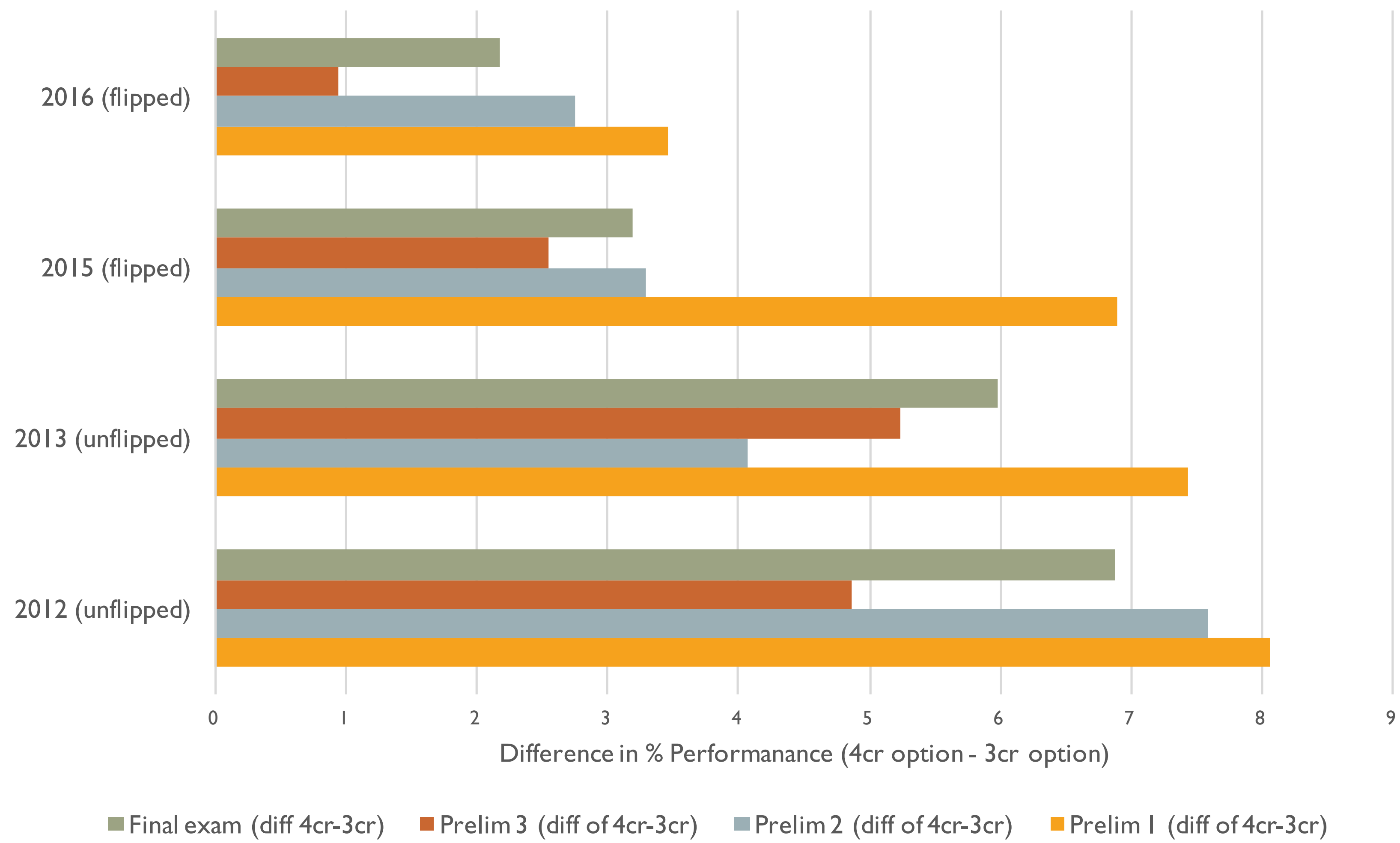


active learning increases →

Results: intro neurobiology

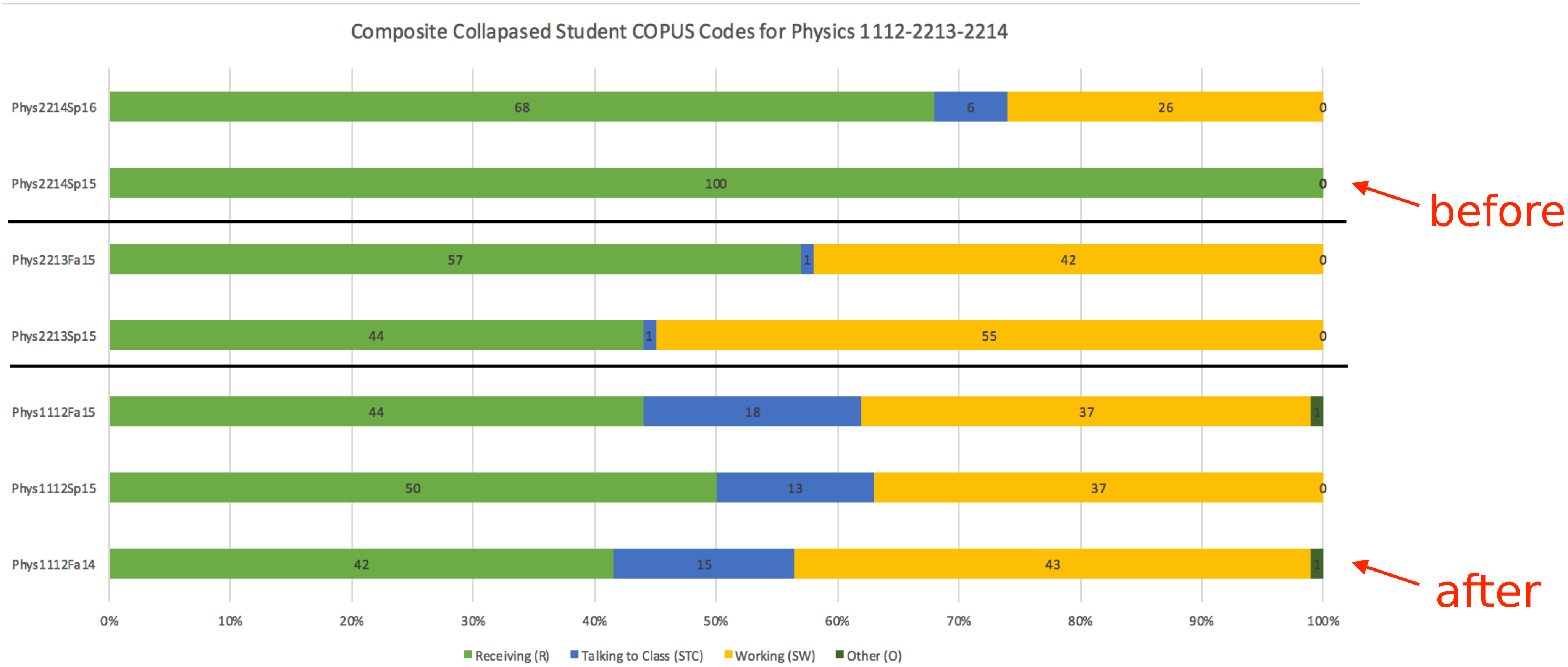
Grade difference: 3+1 versus 3 credit versions of same course.

active learning increases, shrinks grade difference



Results: what are students doing?

Observations show students much more active:

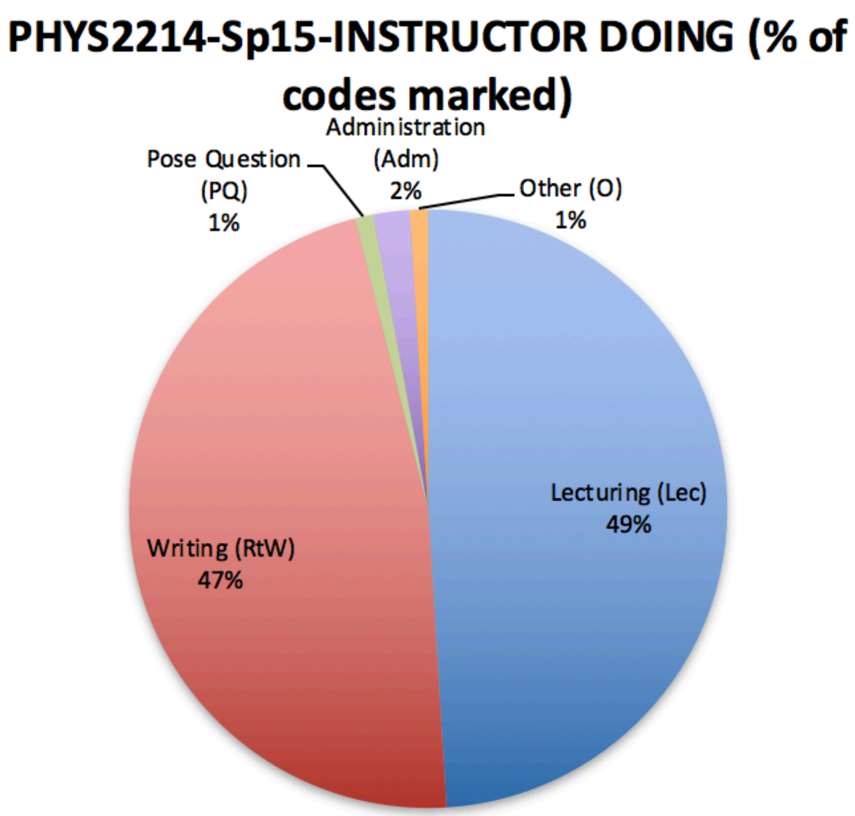


Measure with COPUS observation protocol:

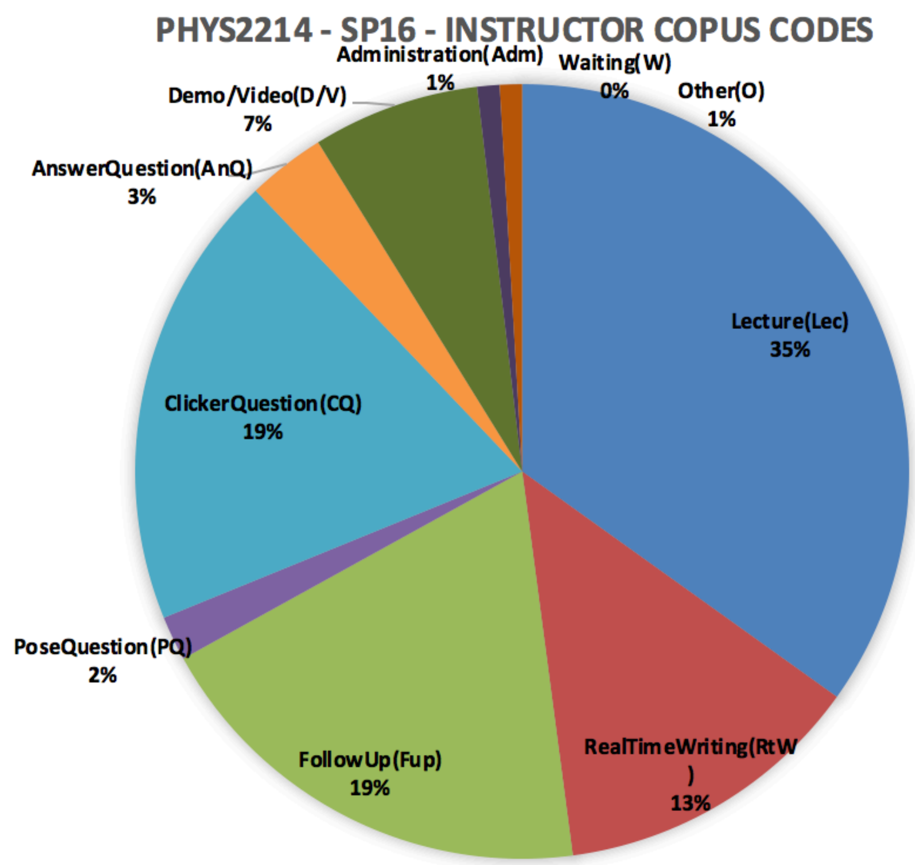
M. K. Smith *et al* CBE–Life Sciences Ed. 12(4) (2013) 618.

Results: what are faculty doing?

Observations show: faculty activities much more varied.



before



after

Results: institutional changes

- > 70 faculty from 9 departments actively involved, affecting many thousands of students each semester.
  - Humanities and Social Sciences as well as STEM.
- Half dozen Physics faculty involved in project; seven or eight more now trying active learning in their courses.
  - Changing teaching culture; teaching much more fun this way.
- Physics hires first PER faculty member; Biology (EEB) hires first BER faculty. Existing faculty adding PER/BER projects.
- Innovations sustained by new teaching teams.
- New competition, university-wide, running now.

Questions?

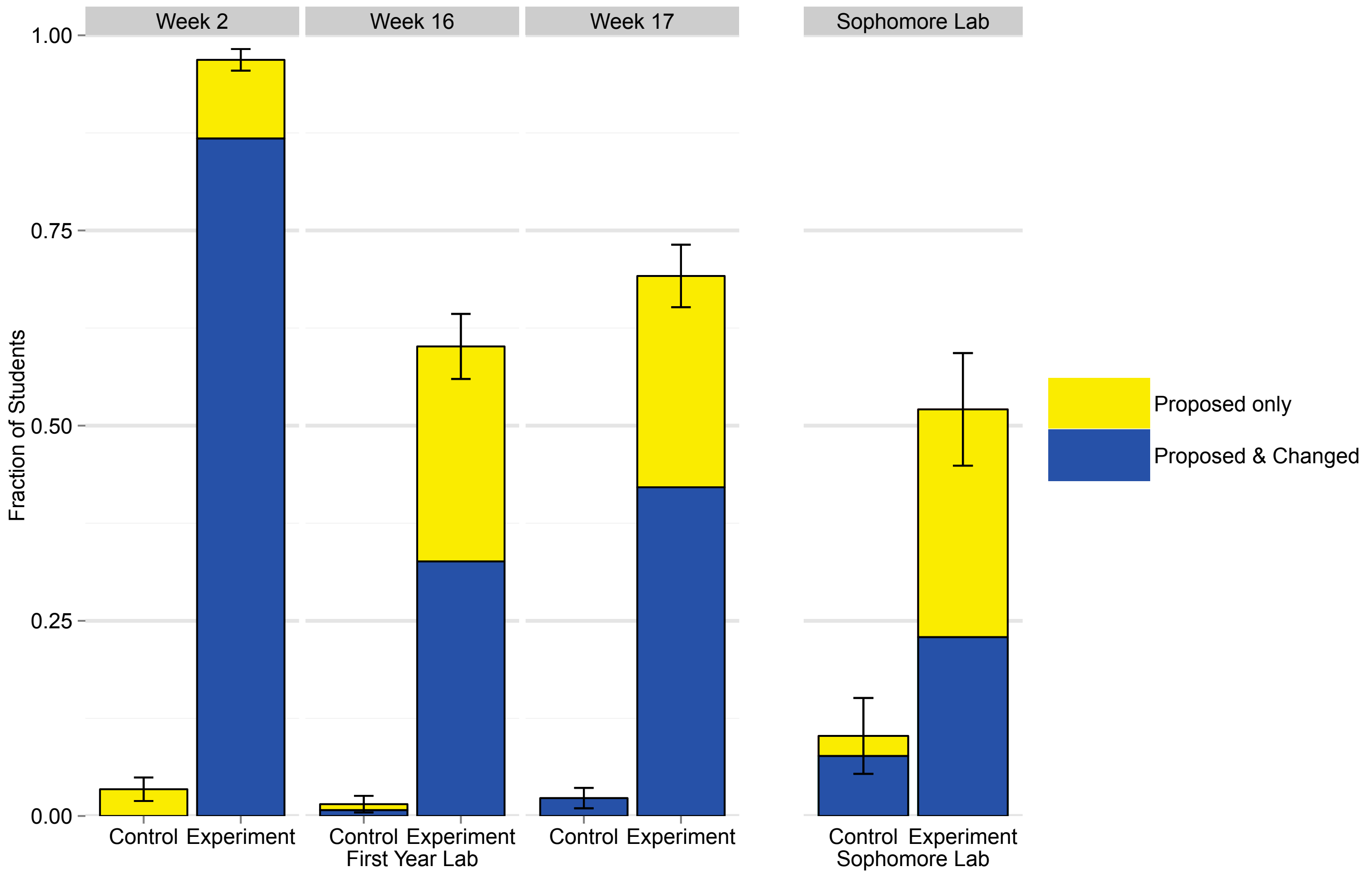
Extras

More references

- Books on how we learn:
  - D. Schwartz et al, *The ABCs of How We Learn.*
  - K. Ericsson et al, *Peak: Secrets of the New Science of Expertise.*
  - S. Ambrose et al, *How Learning Works.*
  - J. Bransford et al, *How People Learn.*
- Research articles on various aspects of active learning: www.cwsei.ubc.ca/resources/papers.htm
- National Academies report on Discipline-Based Education Research (DBER): https://www.nap.edu/catalog/13362/discipline-based-education-research-understanding-and-improving-learning-in-undergraduate

Research: expert learning in lab

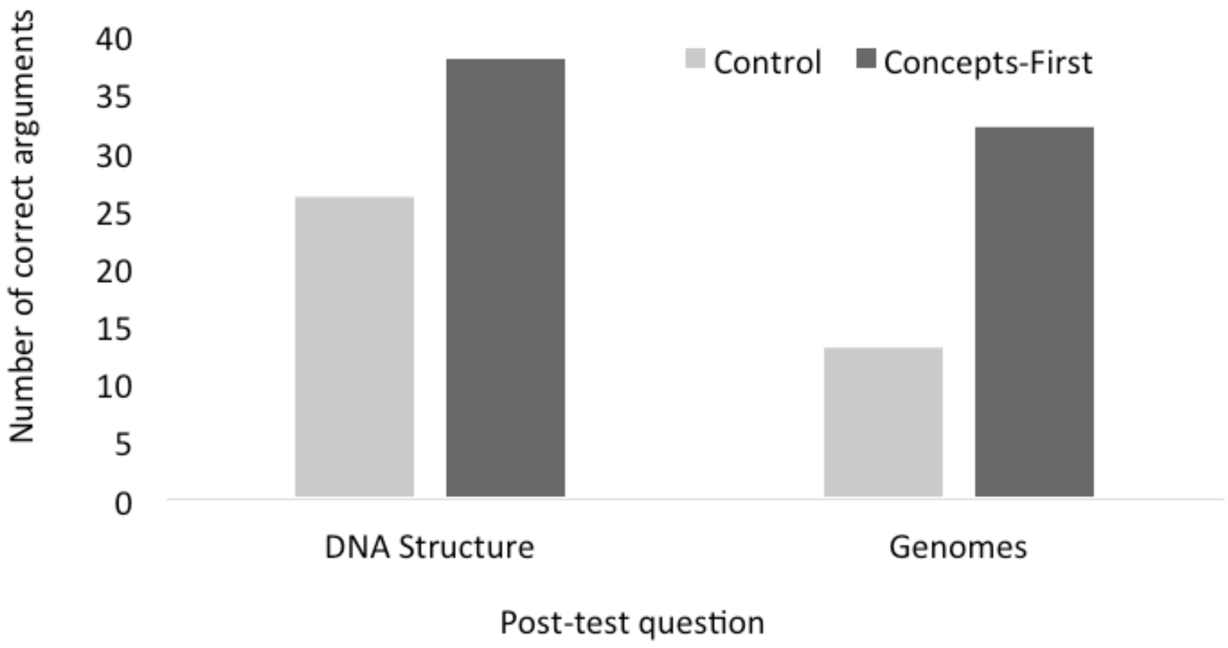
Holmes *et al* (PNAS 112 (2015) 11199) use deliberate practice to teach freshman how to make expert-like decisions about data.



- Students have time to propose/implement changes in experiments.
- Students have time to evaluate/improve models.
- Scaffolding early on, faded as semester progresses.

Research: non-intuitive results

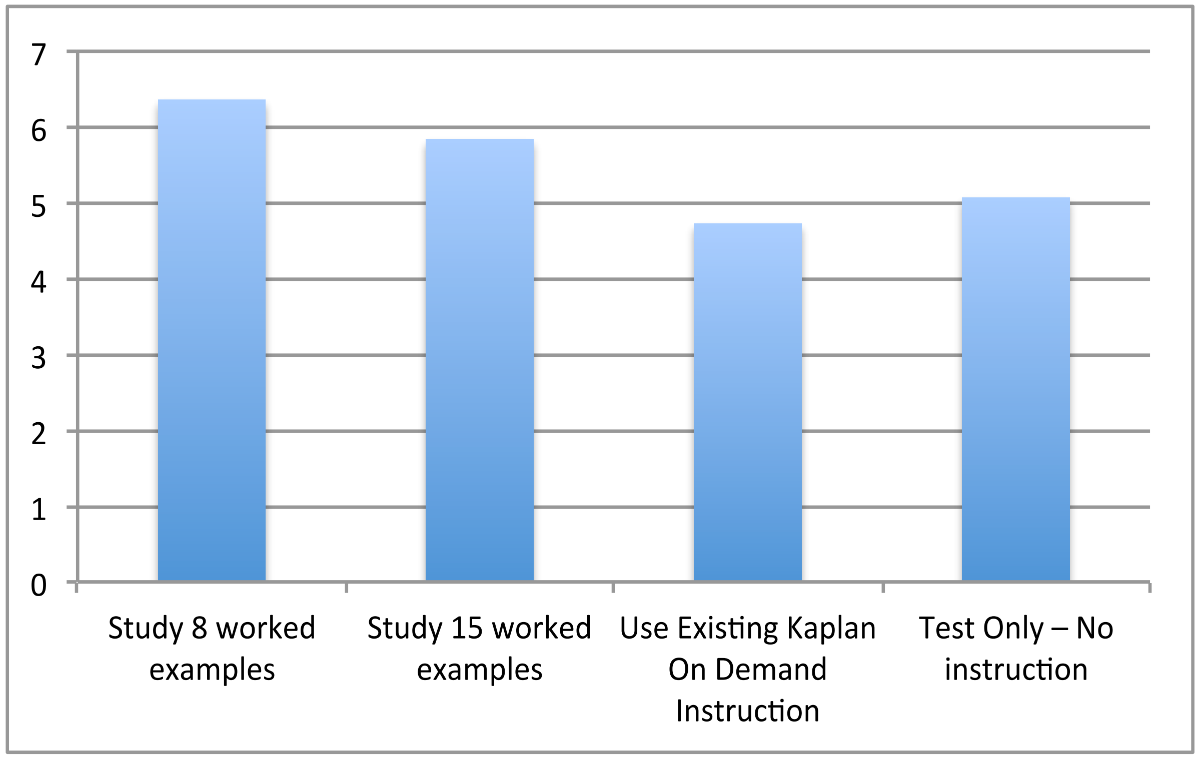
- Mayer *et al* (J. Expt. Psych. 14 (2008) 329) ⇒ extraneous high-interest anecdotes in materials damage learning.
  - Tested text, powerpoint, video. Effect as large as full letter grade.
- McDonnell *et al* (BMB Educ. (2015)) ⇒ introducing concepts and jargon words together in pre-class reading damages learning (intro bio course) — double retention of concepts by teaching concepts first, jargon second.



Students have finite learning bandwidth; cognitive overload damages learning.

- Kaplan study (Bror Saxberg talk at Stanford (2015), paper by Rudman *et al*) ⇒ 8-page powerpoint beats professionally produced interactive video in online training for LSAT logic problems.

Score on Post-Test



N	**153***	**148***	**107**	**84**
Time (mins)	**8.15**	**12.8**	**99.32**	**NA**

powerpoint video nothing

- 8-page powerpoint greatly reduces cognitive load.
- Video (99 min!) has same impact as no training.
- “Learning styles” myth. (Pashler et al, PSPI 9 (2008) 105.)