Does Active Learning Work? A Review of the Research

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Alamosa, CO

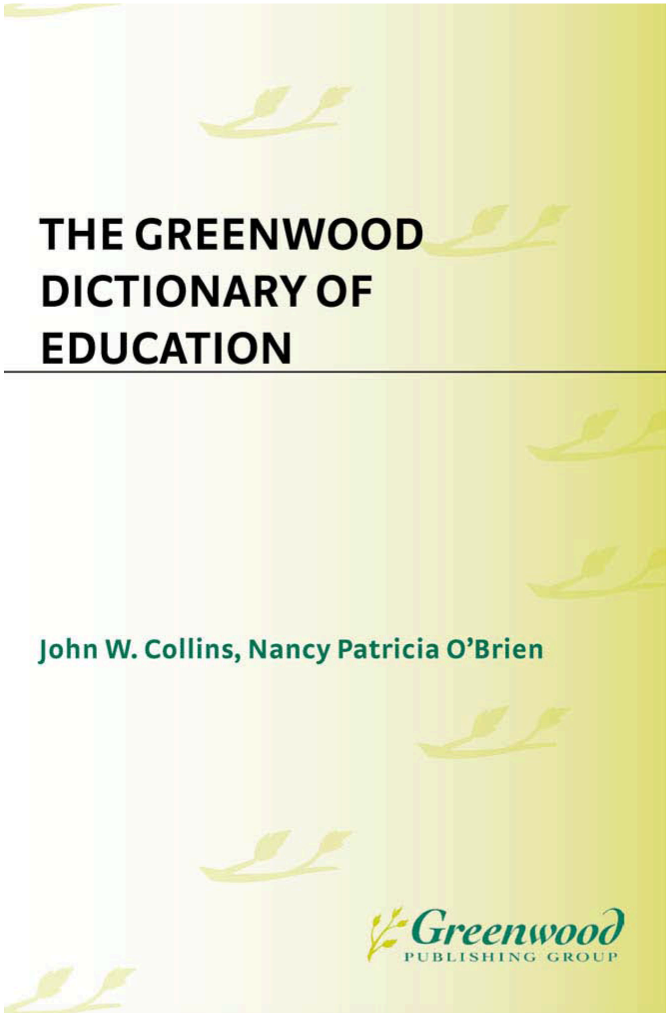
Active Learning in Organic Chemistry cCWCS Workshop, Atlanta
7 – 8 PM, Monday, June 12, 2017.

Think-Pair-Share

What is Active Learning?

Think individually and **write** down your answer.
Pair with a person sitting next to you.
Share your ideas.

What is Active Learning?



active learning

The process of having students engage in some activity that forces them to reflect upon ideas and upon how they are using those ideas. Requiring students to regularly assess their own degree of understanding and skill at handling concepts or problems in a particular discipline. The attainment of knowledge by participating or contributing. The process of keeping students mentally, and often physically, active in their learning through activities that involve them in gathering information, thinking, and problem solving. (dsm, bba)

Collins, J. W., & O'Brien, N. P. (2011). *The Greenwood dictionary of education*. Greenwood.

Key features of Active Learning

Instructor goes from **lecturer** to **learning facilitator.**

Students take on more **responsibility** for their learning.

Active learning leverages **how people learn** best.

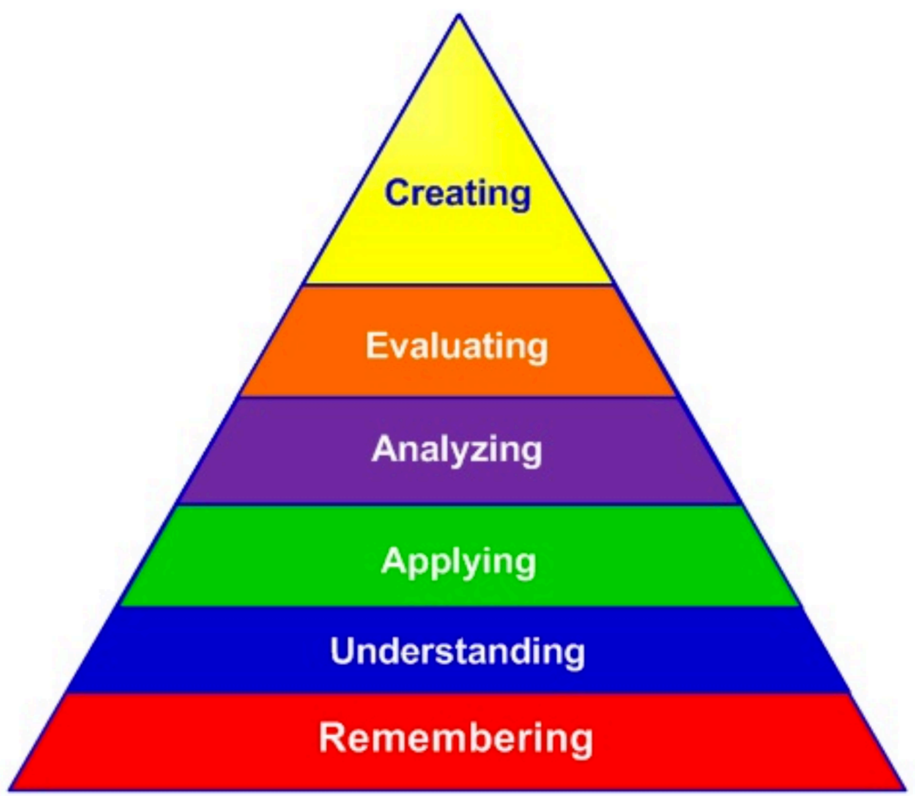
Bloom's Taxonomy

Passive Learning Classroom

Active Learning Classroom

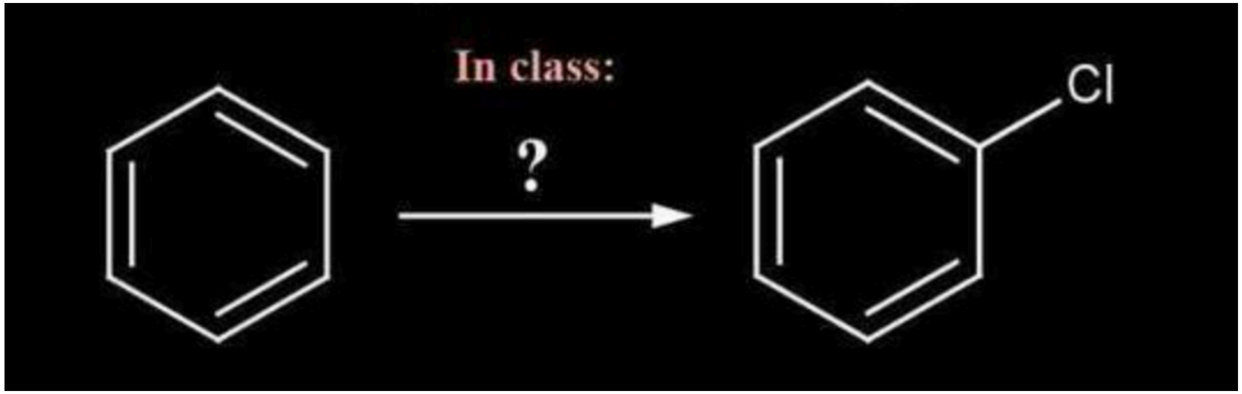
Outside of Class

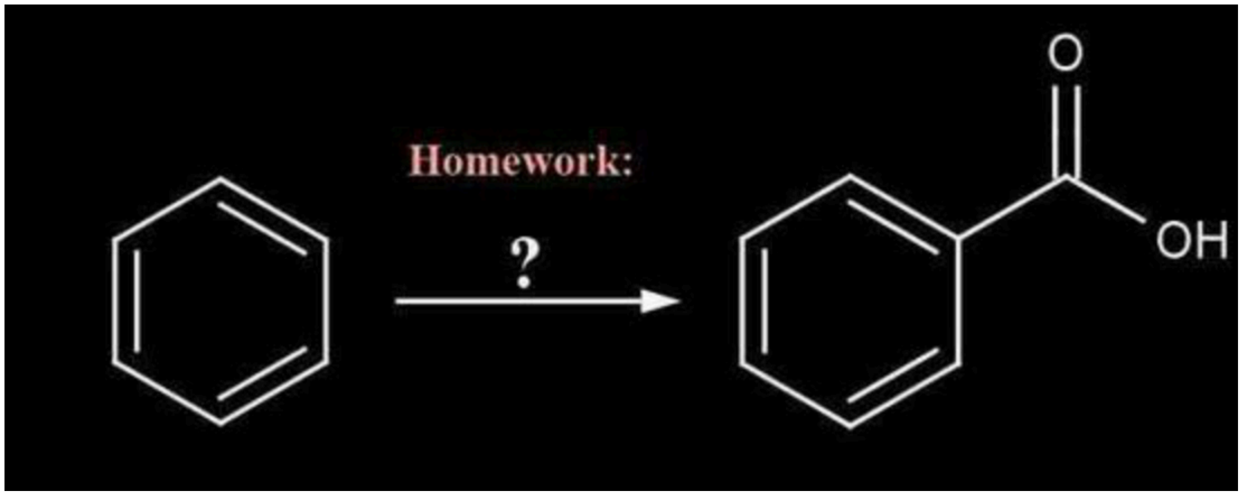
In Class



In Class

Outside of Class


In class:
?
Cl


Homework:
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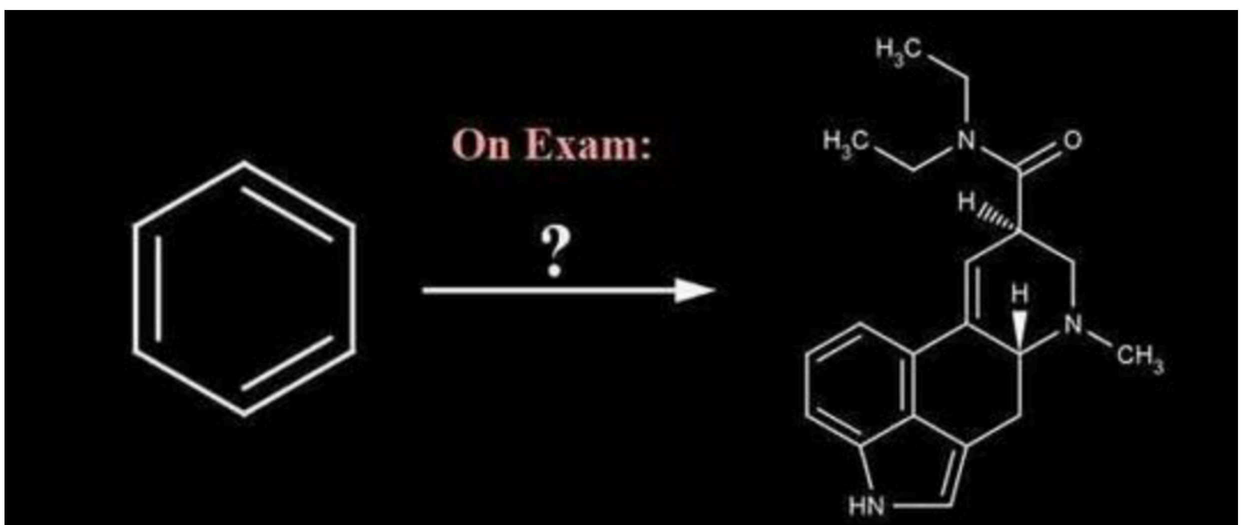
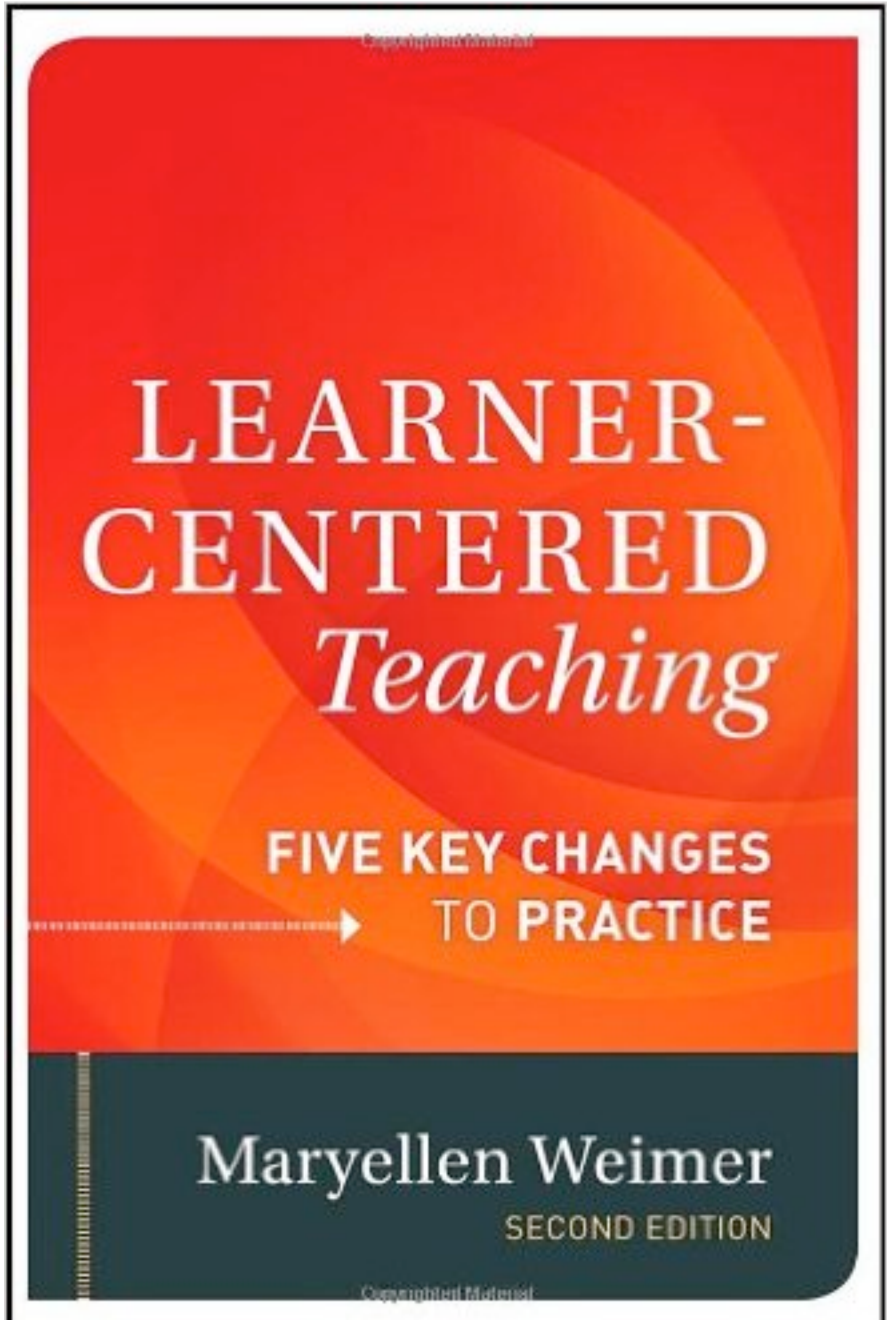
OH


On Exam:
?
H3C
H3C
N
O
H
H
N
CH3
HN

Forms of Active Learning

- Problem-Based Learning (PBL)
- Process Oriented Guided Inquiry Learning (POGIL)
- Peer-Led Team Learning (PLTL)
- Flipped classes
- Just in Time Teaching (JiTT)
- Game Based Learning
- Clickers
- Concept Maps
- Think-Pair-Share


LEARNER-
CENTERED
Teaching
FIVE KEY CHANGES
TO PRACTICE
Maryellen Weimer
SECOND EDITION

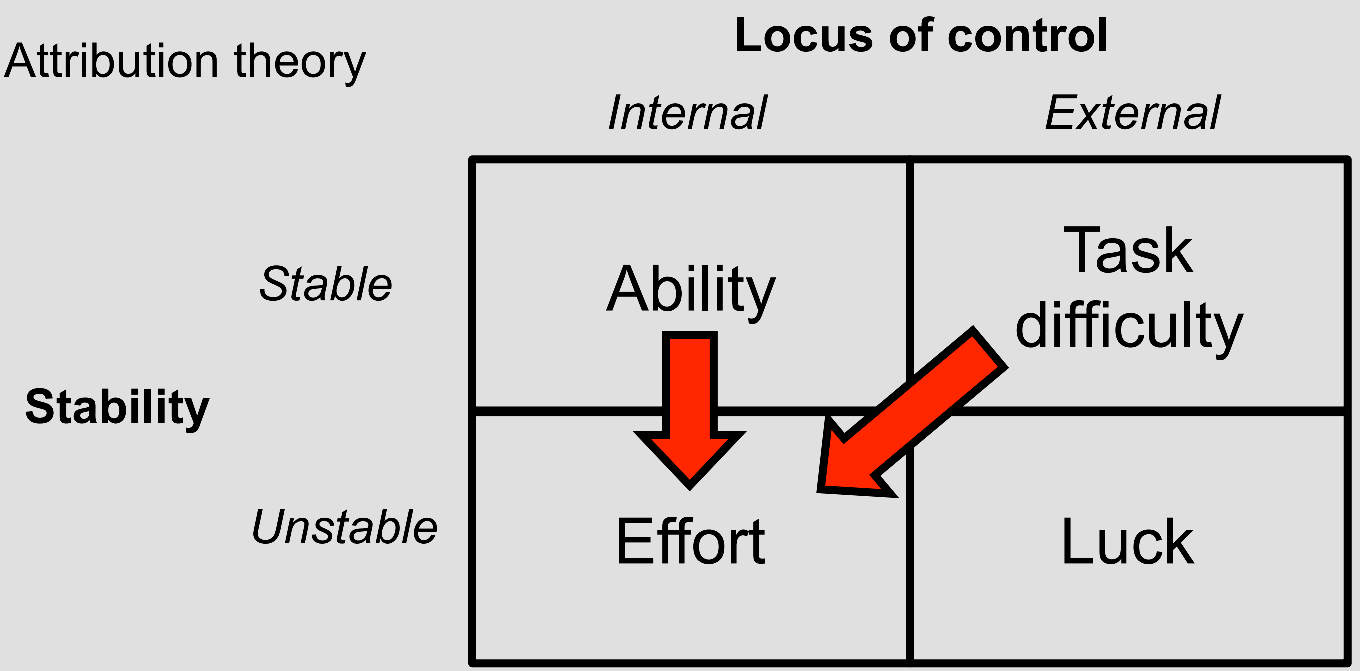
Why Active Learning?

- Learning involves the **active construction** of meaning by the learner.

- Individuals are more likely to learn more when they learn **with others** than when they learn alone.

- Learning **facts** and learning **to do** something are two **different** processes.

- Attribution theory



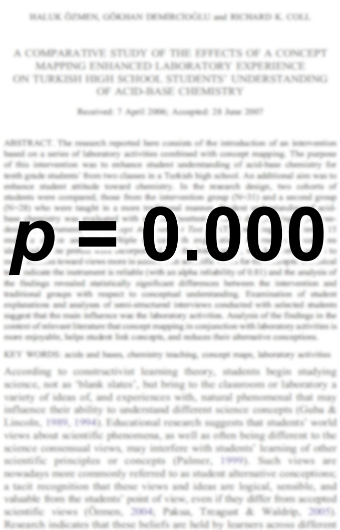
Weimer, M. (2002). *Learner-centered teaching: Five key changes to practice*. John Wiley & Sons.

Is Active Learning Effective?

Is Active Learning Effective?

Many studies, small *N*s → **Contradicting results, non-significant findings**

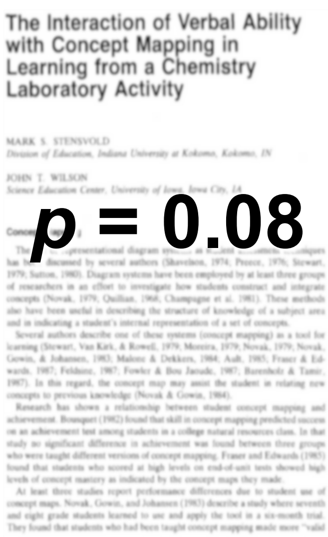
Study 1


HALUK ÖZMEN, GÖKHAN DEMIRCIOĞLU and RICHARD K. COLL

A COMPARATIVE STUDY OF THE EFFECTS OF A CONCEPT MAPPING ENHANCED LABORATORY EXPERIENCE ON TURKISH HIGH SCHOOL STUDENTS' UNDERSTANDING OF ACID-BASE CHEMISTRY

$p = 0.000$

Study 2


The Interaction of Verbal Ability with Concept Mapping in Learning from a Chemistry Laboratory Activity

MARK S. STENSVOLD

JOHN T. WILSON

$p = 0.08$

Study 3


The Concept Map as an Advance Organizer

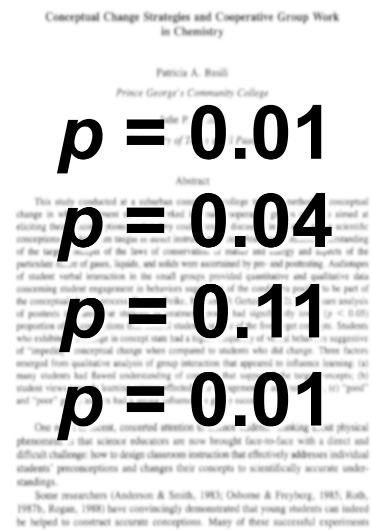
Marvin Willerman

Richard A. Mac Harg

Abstract

$p \leq 0.05$

Study 4


Conceptual Change Strategies and Cooperative Group Work in Chemistry

Patricia A. Basili

Prince George's Community College

Abstract

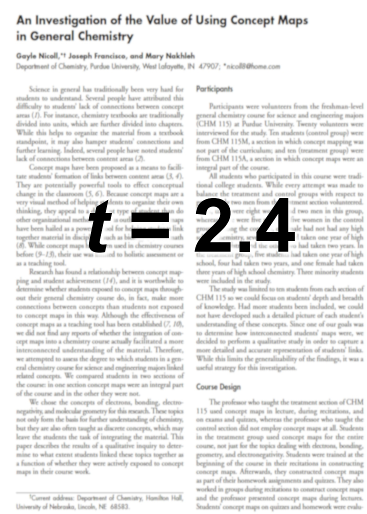
$p = 0.01$

$p = 0.04$

$p = 0.11$

$p = 0.01$

Study 5


An Investigation of the Value of Using Concept Maps in General Chemistry

Gayle Nicoll, Joseph Francisco, and Mary Nakhleh

$t = 2.4$

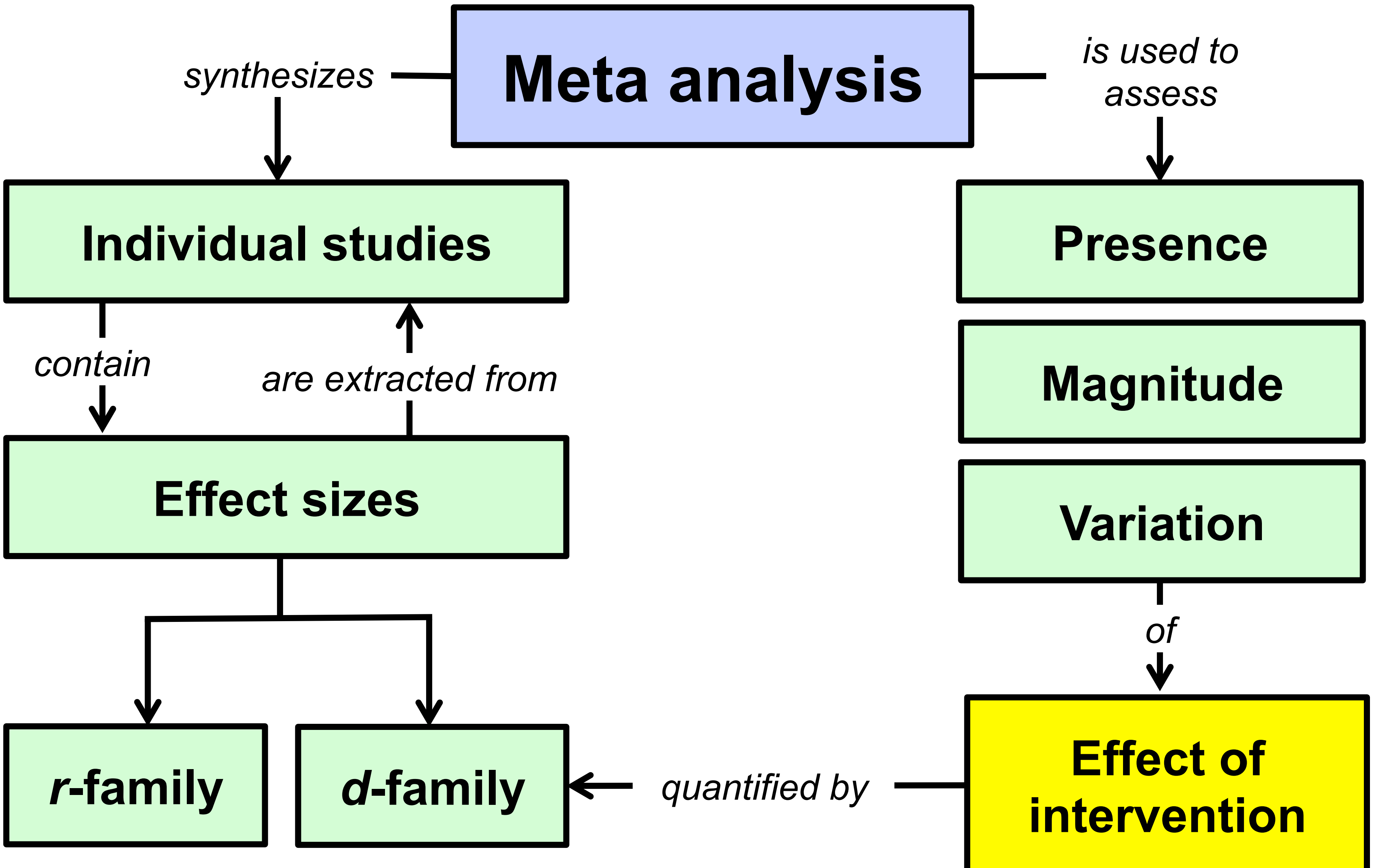
What is a Meta-analysis?

Meta-analysis is a specific type of a **systematic review**.

Meta-analysis uses a **statistical** technique for combining the results of studies.

Meta-analysis can be viewed as "**conducting research about research**."

Concept Map of Meta-analysis



Meta-Analysis by Freeman et al. (2014)

CrossMark

Active learning increases student performance in science, engineering, and mathematics

Scott Freeman[a,1], Sarah L. Eddy[a], Miles McDonough[a], Michelle K. Smith[b], Nnadozie Okoroafor[a], Hannah Jordt[a], and Mary Pat Wenderoth[a]

[a]Department of Biology, University of Washington, Seattle, WA 98195; and [b]School of Biology and Ecology, University of Maine, Orono, ME 04469

Edited* by Bruce Alberts, University of California, San Francisco, CA, and approved April 15, 2014 (received for review October 8, 2013)

To test the hypothesis that lecturing maximizes learning and course performance, we metaanalyzed 225 studies that reported data on examination scores or failure rates when comparing student performance in undergraduate science, technology, engineering, and mathematics (STEM) courses under traditional lecturing versus active learning. The effect sizes indicate that on average, student performance on examinations and concept inventories increased by 0.47 SDs under active learning (n = 158 studies), and that the odds ratio for failing was 1.95 under traditional lecturing (n = 67 studies). These results indicate that average examination scores improved by about 6% in active learning sections, and that students in classes with traditional lecturing were 1.5 times more likely to fail than were students in classes with active learning. Heterogeneity analyses indicated that both results hold across the STEM disciplines, that active learning increases scores on concept inventories more than on course examinations, and that active learning appears effective across all class sizes—although the greatest effects are in small ($n \leq 50$) classes. Trim and fill analyses and fail-safe n calculations suggest that the results are not due to publication bias. The results also appear robust to variation in the methodological rigor of the included studies, based on the quality of controls over student quality and instructor identity. This is the largest and most comprehensive metaanalysis of undergraduate STEM education published to date. The results raise questions about the continued use of traditional lecturing as a control in research studies, and support active learning as the preferred, empirically validated teaching practice in regular classrooms.

constructivism | undergraduate education | evidence-based teaching | scientific teaching

Lecturing has been the predominant mode of instruction since universities were founded in Western Europe over 900 y ago (1). Although theories of learning that emphasize the need for students to construct their own understanding have challenged the theoretical underpinnings of the traditional, instructor-focused, "teaching by telling" approach (2, 3), to date there has been no quantitative analysis of how constructivist versus exposition-centered methods impact student performance in undergraduate courses across the science, technology, engineering, and mathematics (STEM) disciplines. In the STEM classroom, should we ask or should we tell?

Addressing this question is essential if scientists are committed to teaching based on evidence rather than tradition (4). The answer could also be part of a solution to the "pipeline problem" that some countries are experiencing in STEM education: For example, the observation that less than 40% of US students who enter university with an interest in STEM, and just 20% of STEM-interested underrepresented minority students, finish with a STEM degree (5).

To test the efficacy of constructivist versus exposition-centered course designs, we focused on the design of class sessions—as opposed to laboratories, homework assignments, or other exercises. More specifically, we compared the results of experiments that documented student performance in courses with at least some active learning versus traditional lecturing, by metaanalyzing 225 studies in the published and unpublished literature. The active learning interventions varied widely in intensity and implementation, and included approaches as diverse as occasional group problem-solving, worksheets or tutorials completed during class, use of personal response systems with or without peer instruction, and studio or workshop course designs. We followed guidelines for best practice in quantitative reviews (*SI Materials and Methods*), and evaluated student performance using two outcome variables: (*i*) scores on identical or formally equivalent examinations, concept inventories, or other assessments; or (*ii*) failure rates, usually measured as the percentage of students receiving a D or F grade or withdrawing from the course in question (DFW rate).

The analysis, then, focused on two related questions. Does active learning boost examination scores? Does it lower failure rates?

Results

The overall mean effect size for performance on identical or equivalent examinations, concept inventories, and other assessments was a weighted standardized mean difference of 0.47 (Z = 9.781, $P << 0.001$)—meaning that on average, student performance increased by just under half a SD with active learning compared with lecturing. The overall mean effect size for failure rate was an odds ratio of 1.95 (Z = 10.4, $P << 0.001$). This odds ratio is equivalent to a risk ratio of 1.5, meaning that on average, students in traditional lecture courses are 1.5 times more likely to fail than students in courses with active learning. Average failure rates were 21.8% under active learning but 33.8% under traditional lecturing—a difference that represents a 55% increase (Fig. 1 and Fig. S1).

Significance

The President's Council of Advisors on Science and Technology has called for a 33% increase in the number of science, technology, engineering, and mathematics (STEM) bachelor's degrees completed per year and recommended adoption of empirically validated teaching practices as critical to achieving that goal. The studies analyzed here document that active learning leads to increases in examination performance that would raise average grades by a half a letter, and that failure rates under traditional lecturing increase by 55% over the rates observed under active learning. The analysis supports theory claiming that calls to increase the number of students receiving STEM degrees could be answered, at least in part, by abandoning traditional lecturing in favor of active learning.

Author contributions: S.F. and M.P.W. designed research; S.F., M.M., M.K.S., N.O., H.J., and M.P.W. performed research; S.F. and S.L.E. analyzed data; and S.F., S.L.E., M.M., M.K.S., N.O., H.J., and M.P.W. wrote the paper.

The authors declare no conflict of interest.

*This Direct Submission article had a prearranged editor.

Freely available online through the PNAS open access option.

See Commentary on page 8319.

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www.pnas.org/cgi/doi/10.1073/pnas.1319030111

Cited by 1141

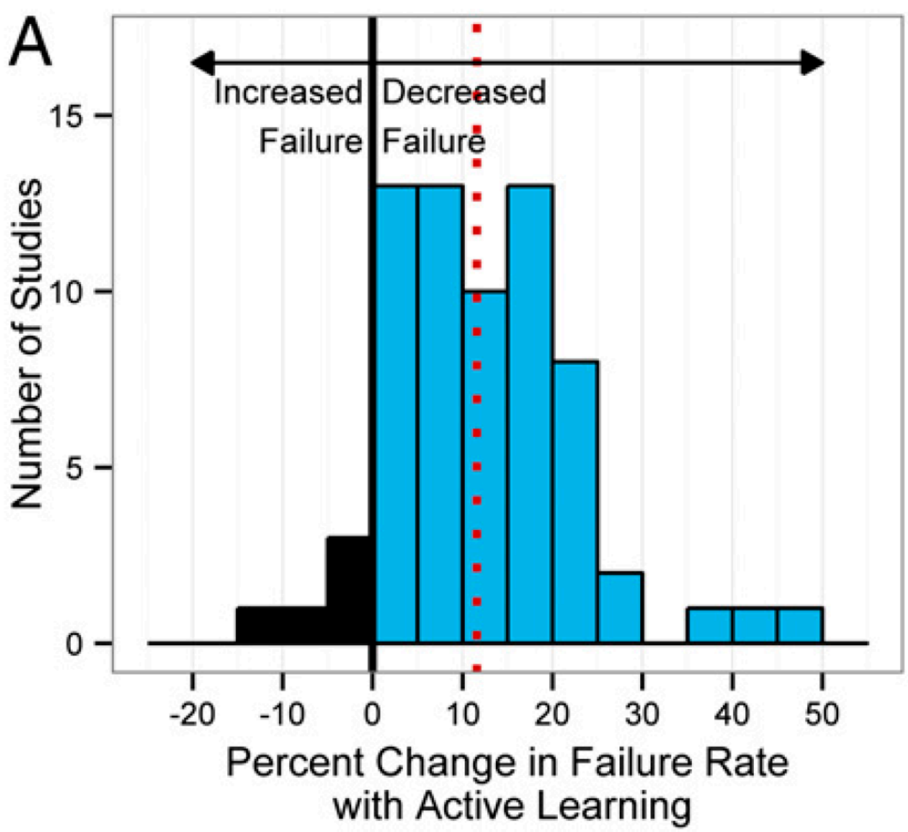
Meta-analyzed 225 studies that reported data on exam scores and failure rates in undergraduate STEM courses (traditional lecture vs active learning).

Two fundamental results:

- Students in traditional classes have lower grades (1/2 SD).
- Students in traditional lecture sections were 1.5 times more likely to fail.

Freeman, S., Eddy, S. L., McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H., & Wenderoth, M. P. (2014). Active learning increases student performance in science, engineering, and mathematics. Proceedings of the National Academy of Sciences, 111(23), 8410-8415.

Failure Rates



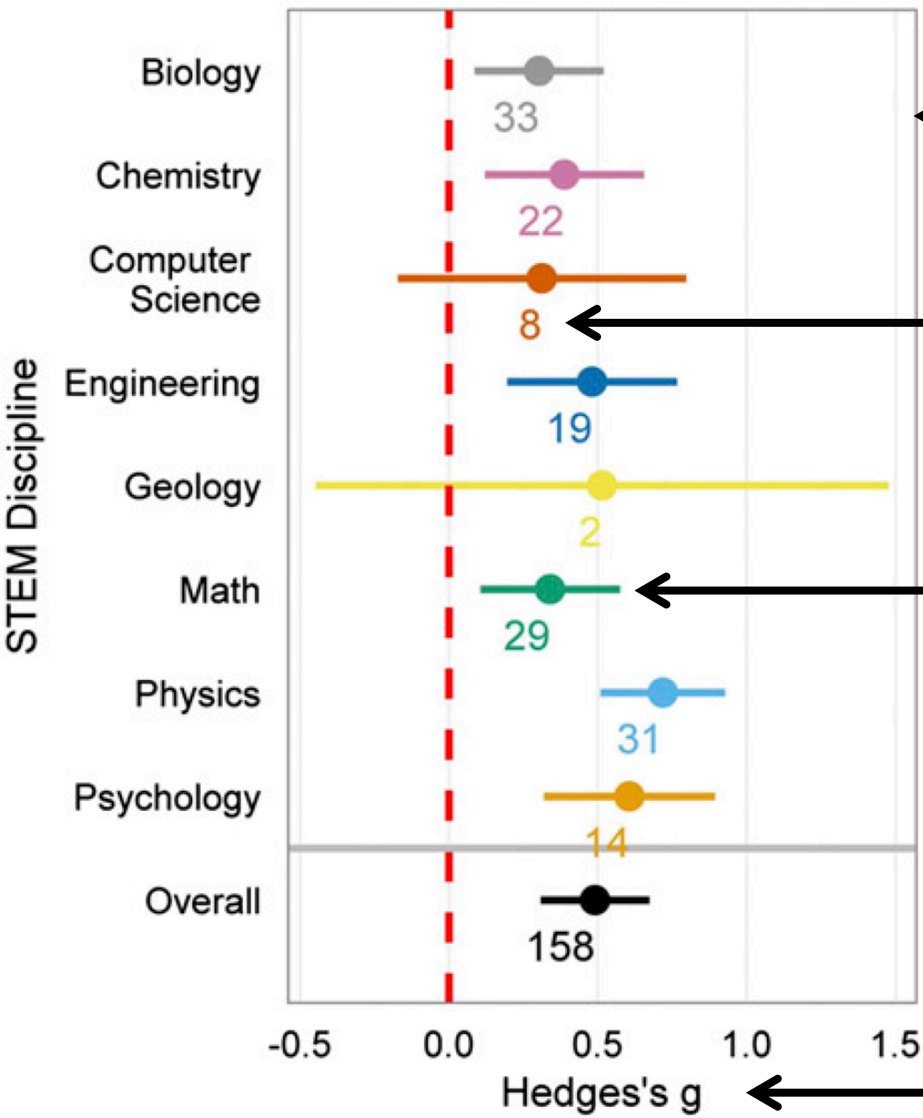
67 studies reported failure rate data

Average failure rate
21.8% active learning
33.8% traditional lecture

Risk ratio = 1.5

Students in lecture are 1.5x more likely to fail

Effect Sizes by Discipline



Forest plot

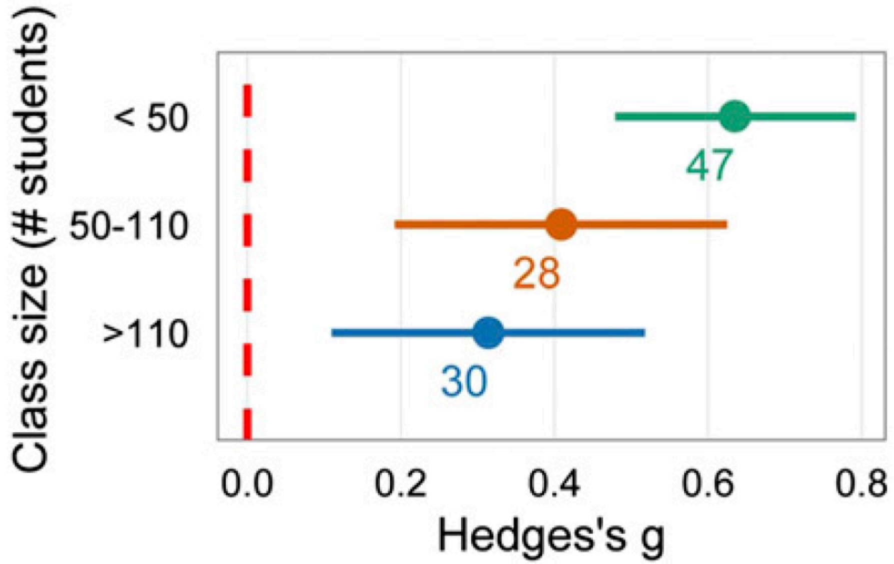
Number of independent studies

95% confidence interval

Effect size of interventions

$$ES = \frac{\bar{X}_{treatment} - \bar{X}_{control}}{SD_{pooled}}$$

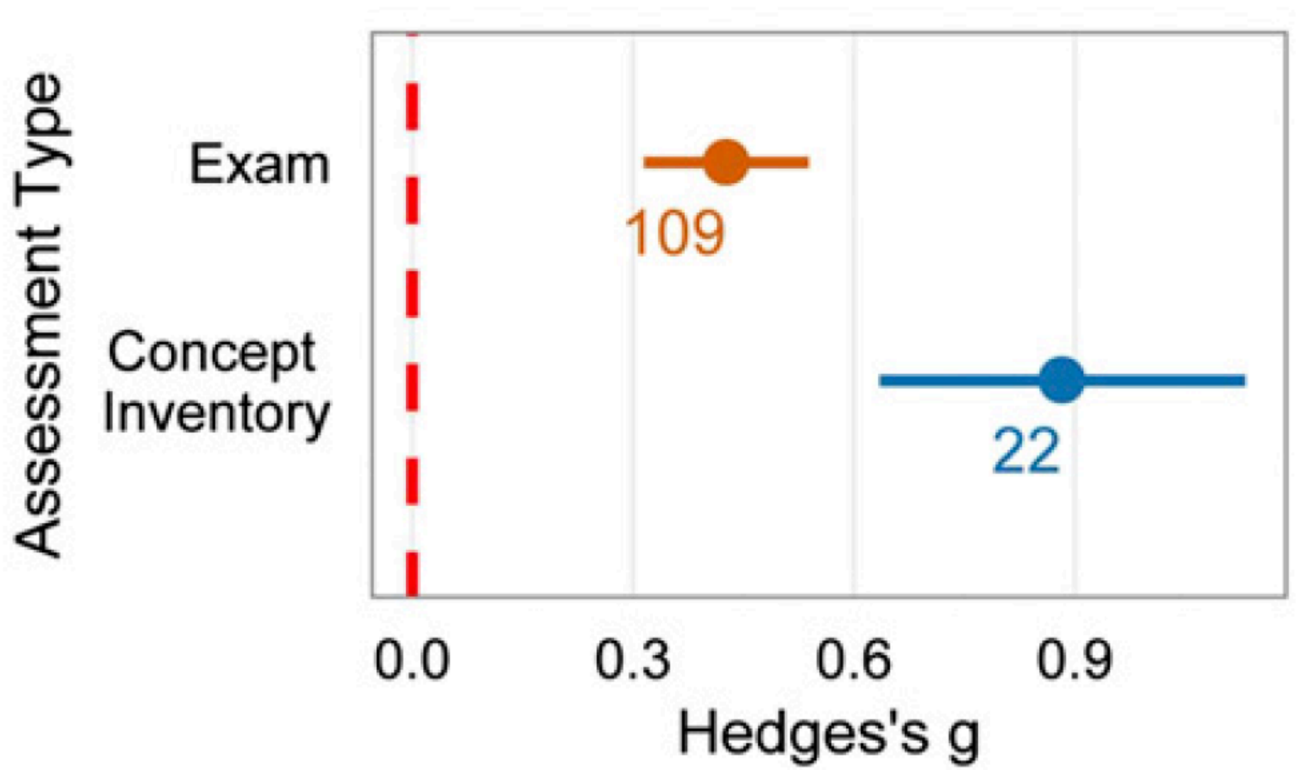
Class Size



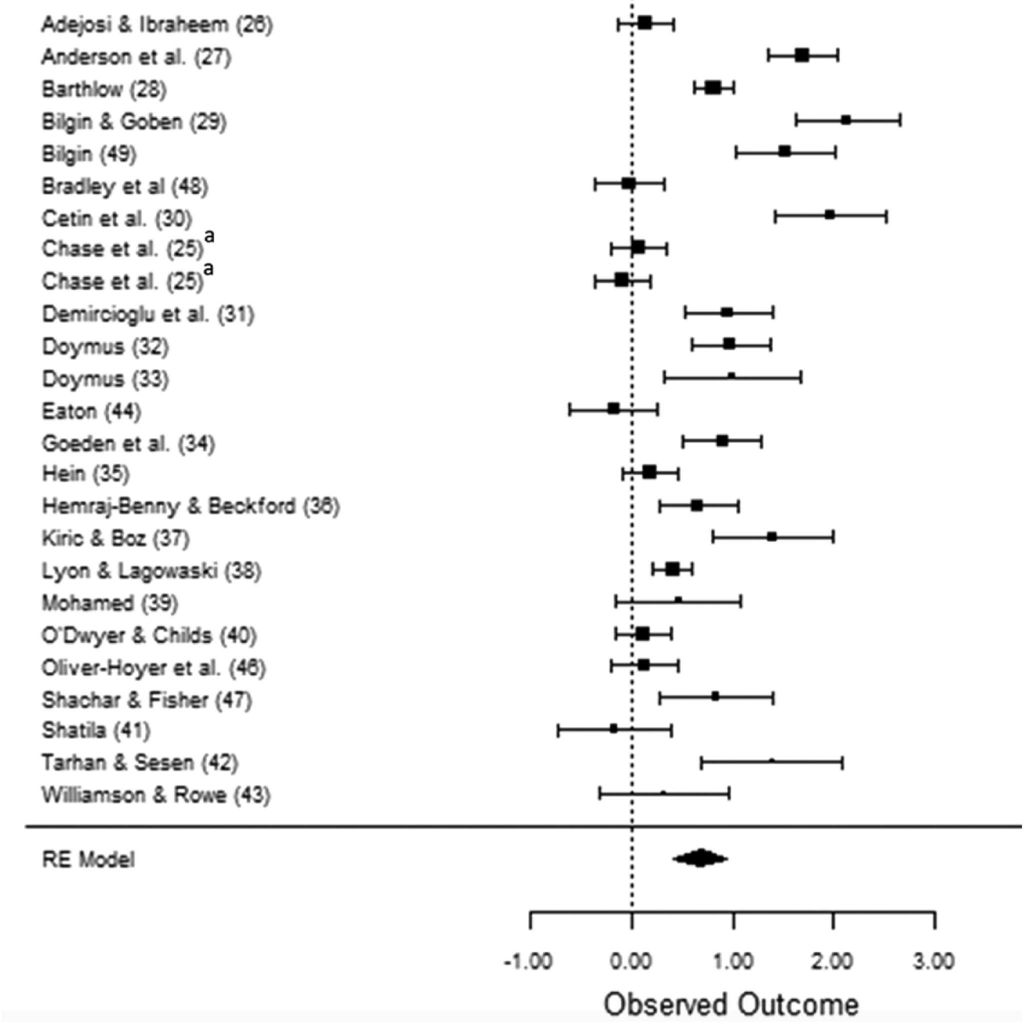
Poll Question: Which of the following can you conclude from this graph?

- **A.** Active learning is more effective in small classes
- **B.** Active learning is more effective in large classes
- **C.** Active learning is equally effective in small and large classes

Assessment Type



Cooperative Learning in Chemistry



Meta-analyzed 25 studies that investigate the effectiveness of CL in chemistry.

***ES* = 0.68**

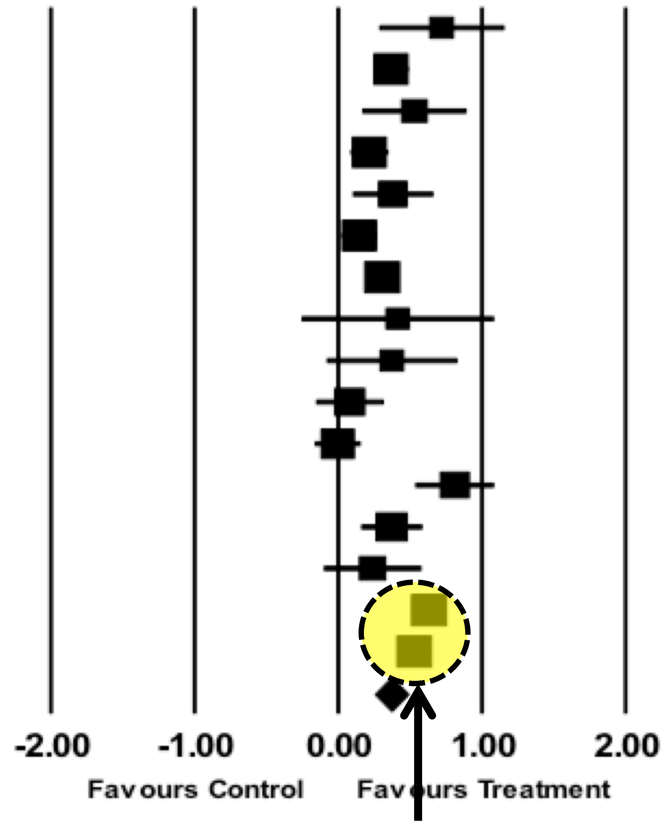
Median student performance in a CL group would be at the 75th percentile when compared to that of a student in a traditional group performing at the 50th percentile.

Warfa, A. R. M. (2015). Using Cooperative Learning to Teach Chemistry: A Meta-analytic Review. *Journal of Chemical Education*, *93*(2), 248-255.

PLTL in Chemistry

Study name	Outcome	Hedges's g	Lower limit	Upper limit
		Statistics for each study		
Akinyele, 2010	Achievement	0.720	0.282	1.158
Baez-Galib et al., 2015	Passing	0.367	0.240	0.494
Chan & Bauer, 2015	Achievement	0.530	0.163	0.897
Hockings et al., 2008	Passing	0.217	0.080	0.354
Lewis & Lewis, 2005	Achievement	0.381	0.096	0.666
Lewis & Lewis, 2008	Achievement	0.147	0.020	0.273
Lewis, 2011	Achievement	0.306	0.207	0.405
Lyon & Lagowski, 2008	Achievement	0.414	-0.259	1.087
McCreary et al., 2006	Achievement	0.374	-0.084	0.832
Mitchell et al., 2012	Passing	0.081	-0.157	0.319
Rein & Brookes, 2015	Achievement	-0.003	-0.166	0.159
Shields et al., 2012	Achievement	0.811	0.533	1.090
Steward et al., 2007	Passing	0.372	0.155	0.589
Tenney & Houck, 2003	Passing	0.239	-0.104	0.583
Tien et al., 2002	Achievement	0.632	0.537	0.727
Wamser, 2006	Passing	0.529	0.420	0.638
		0.365	0.250	0.480

Hedges's g and 95% CI

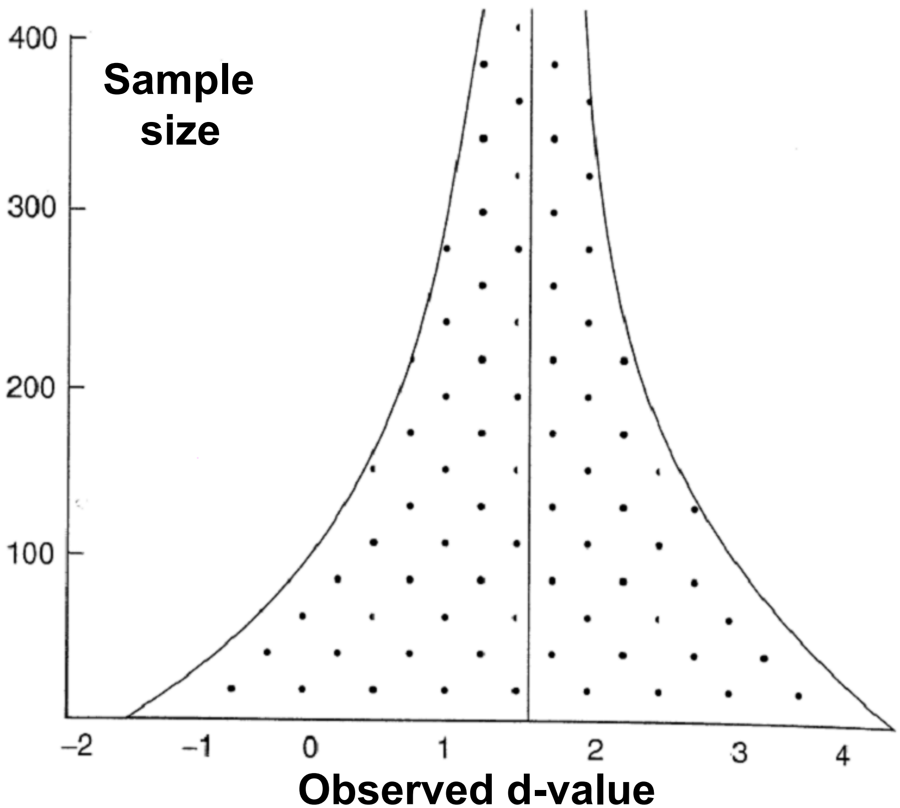


Organic Chemistry

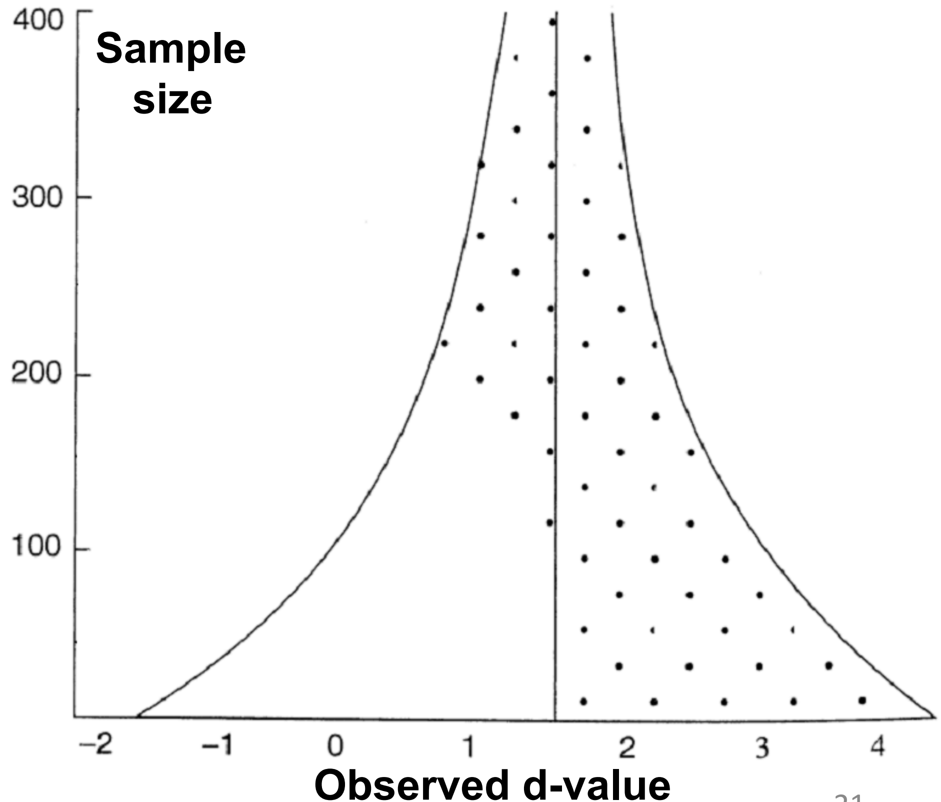
Leontyev, A., Chase, A., Pulos, S., & Varma-Nelson, P. (2017). *Assessment of the Effectiveness of Instructional Interventions Using a Comprehensive Meta-Analysis Package* in Gupta, T. (Ed), Computer-Aided Data Analysis in Chemical Education Research (CADACER) Advances and Avenues. ACS Symposium book. Accepted.

Funnel plot

Symmetric

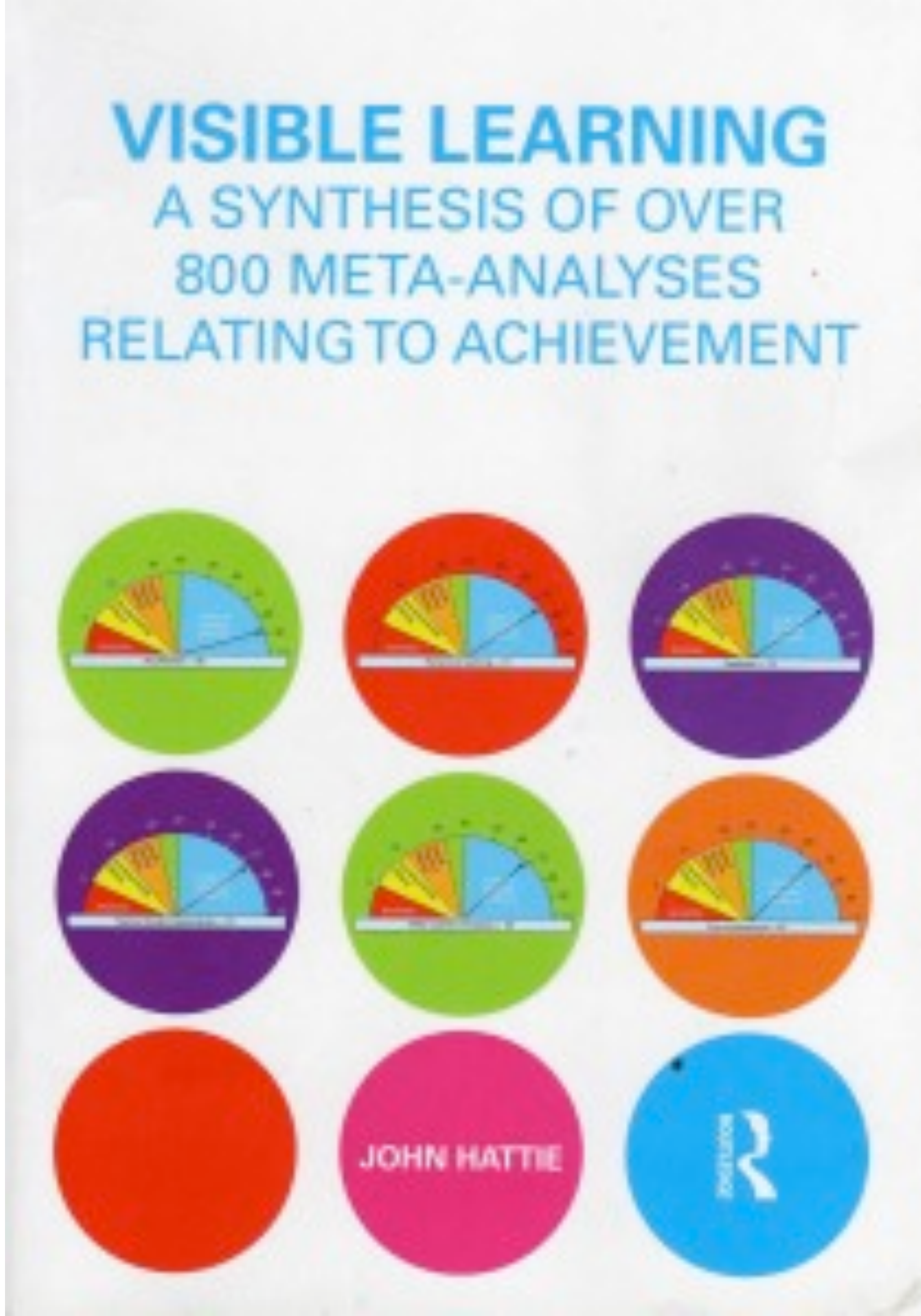


Asymmetric

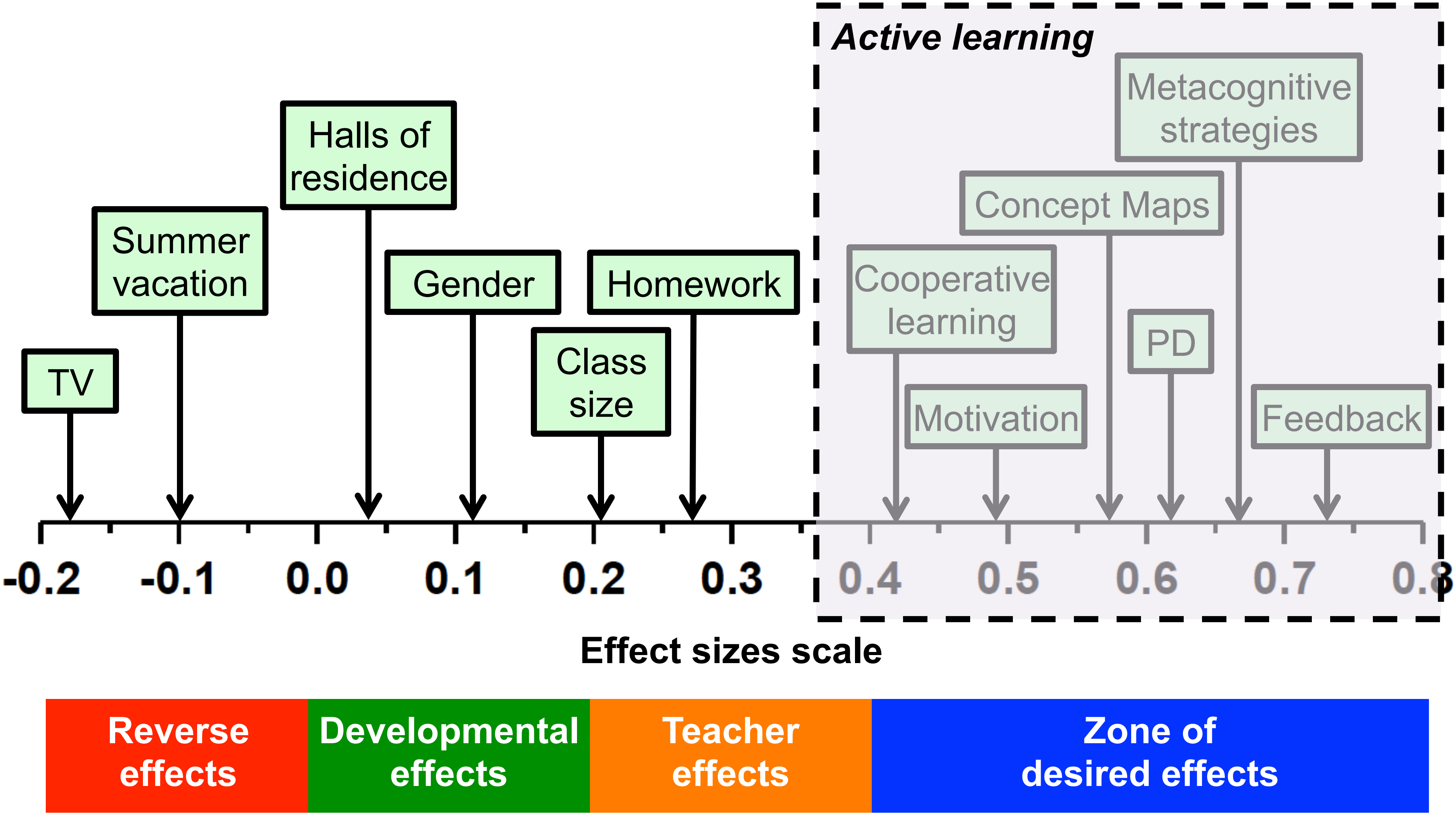


Where are small, non-significant studies?

File drawer effect


VISIBLE LEARNING
A SYNTHESIS OF OVER
800 META-ANALYSES
RELATING TO ACHIEVEMENT
JOHN HATTIE

Effect sizes interpretation



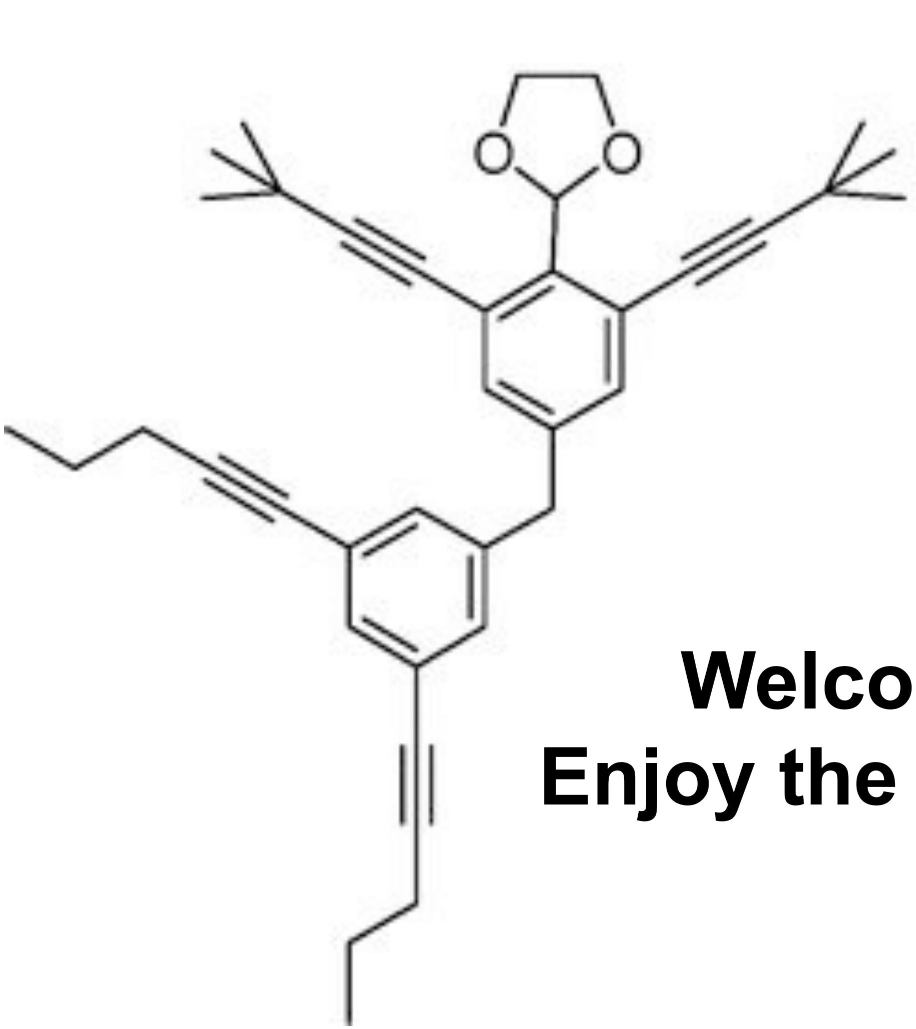
Hattie, J. (2009). *Visible learning: A synthesis of over 800 meta-analyses relating to achievement*. New York: Routledge.

The Muddiest Point

most surprising

What was the ~~muddiest~~ point in this lecture?

Answer the question on 3x5 cards in 2-3 sentences. Do not write your names.



Welcome and Enjoy the Workshop!