

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

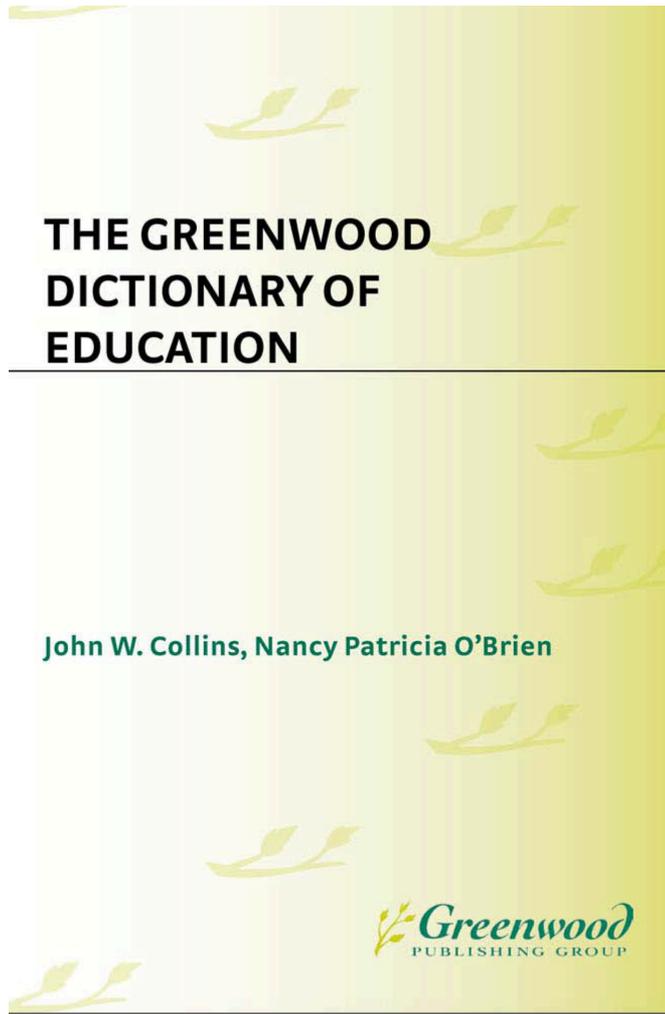
What is Active Learning?

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)

Key features of Active Learning

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

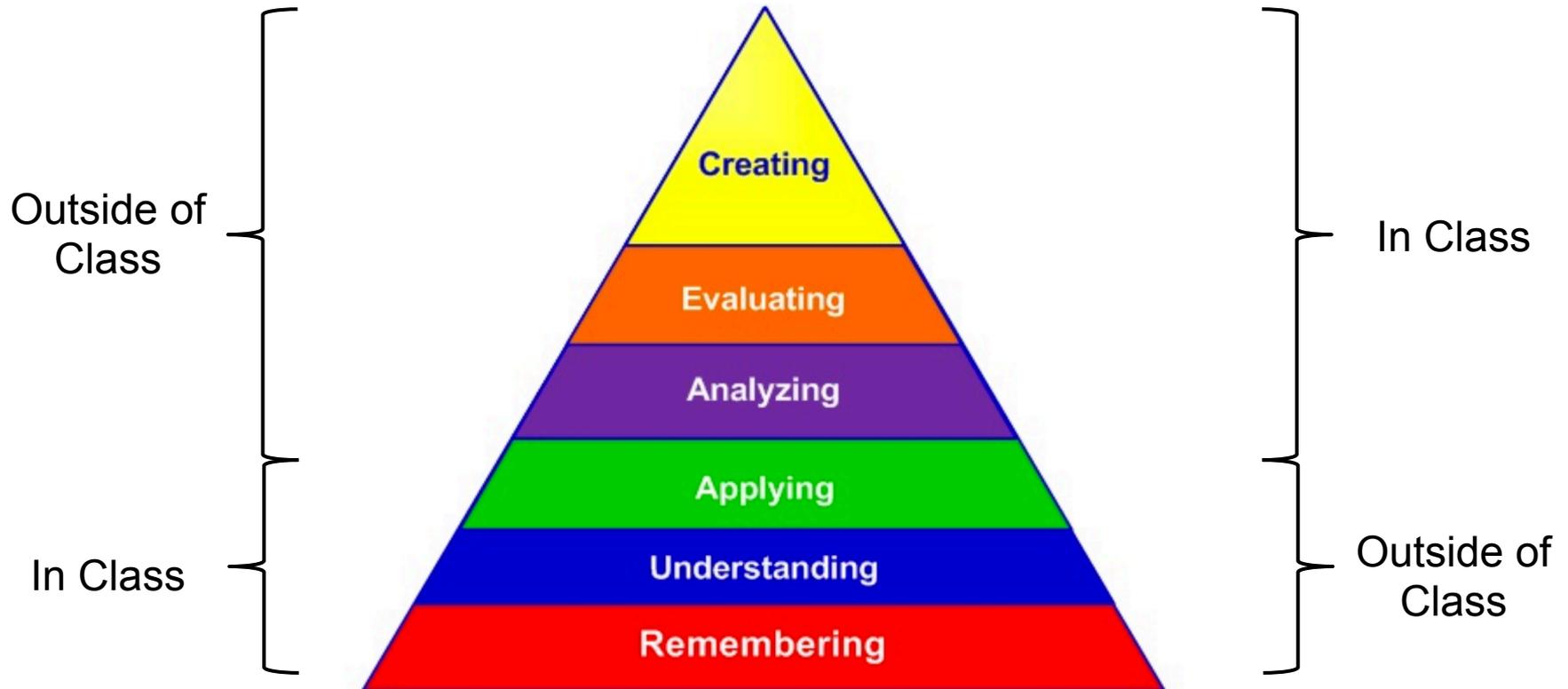
Students take on more **responsibility** for their learning.

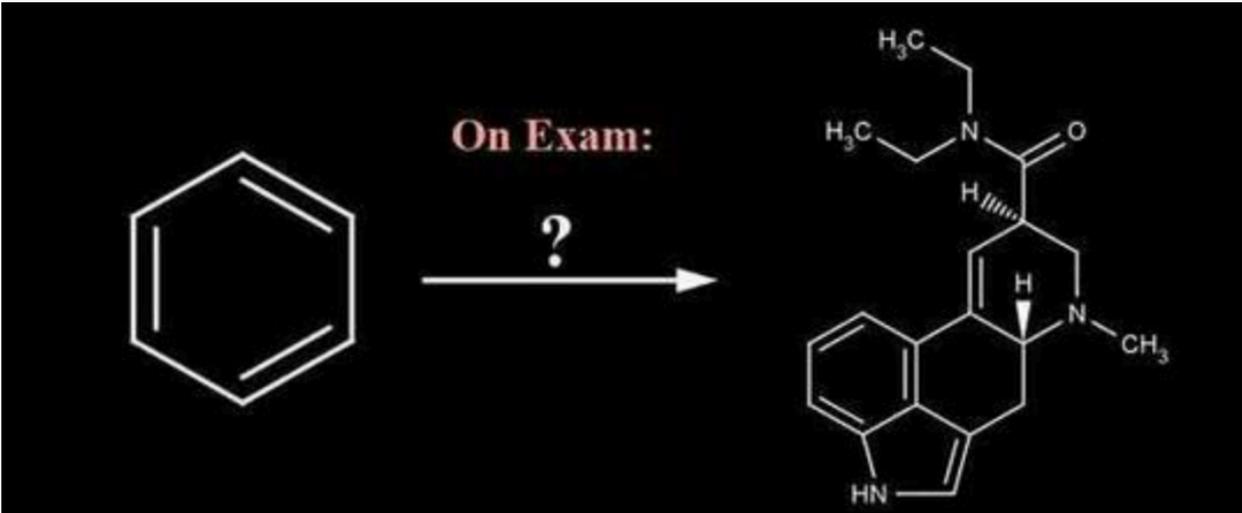
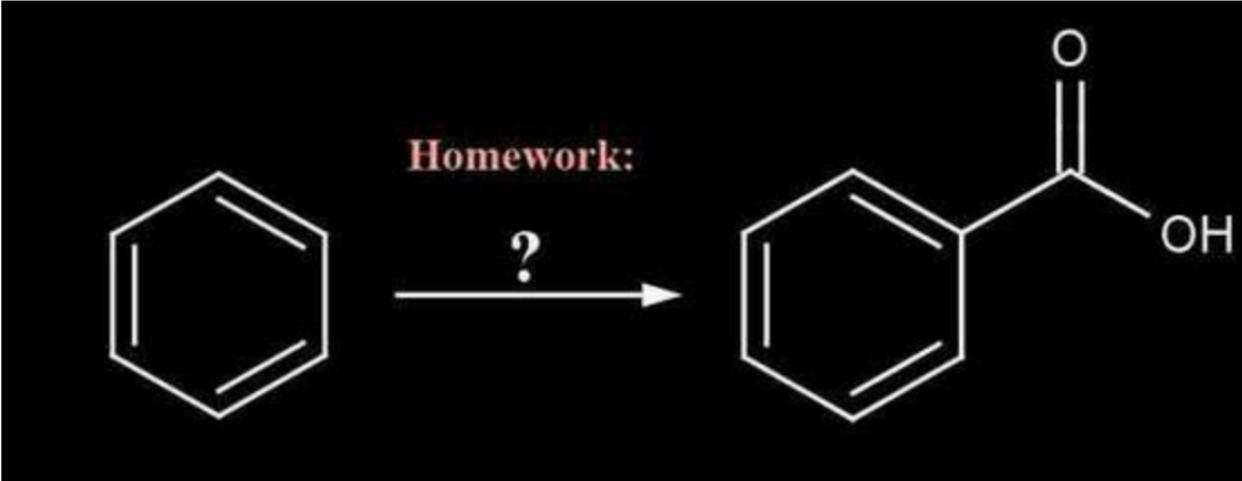
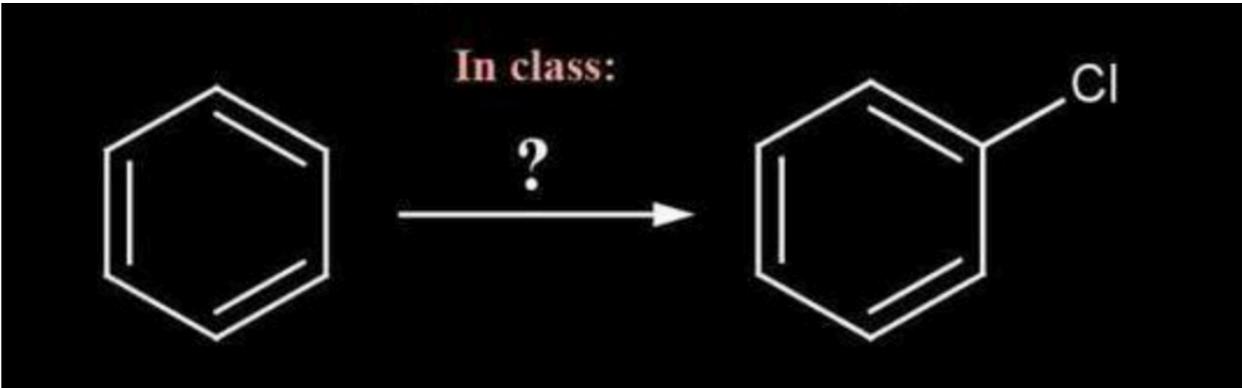
Active learning leverages **how people learn** best.

Bloom's Taxonomy

**Passive Learning
Classroom**

**Active Learning
Classroom**





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

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LEARNER- CENTERED *Teaching*

FIVE KEY CHANGES
▶ TO PRACTICE

Maryellen Weimer

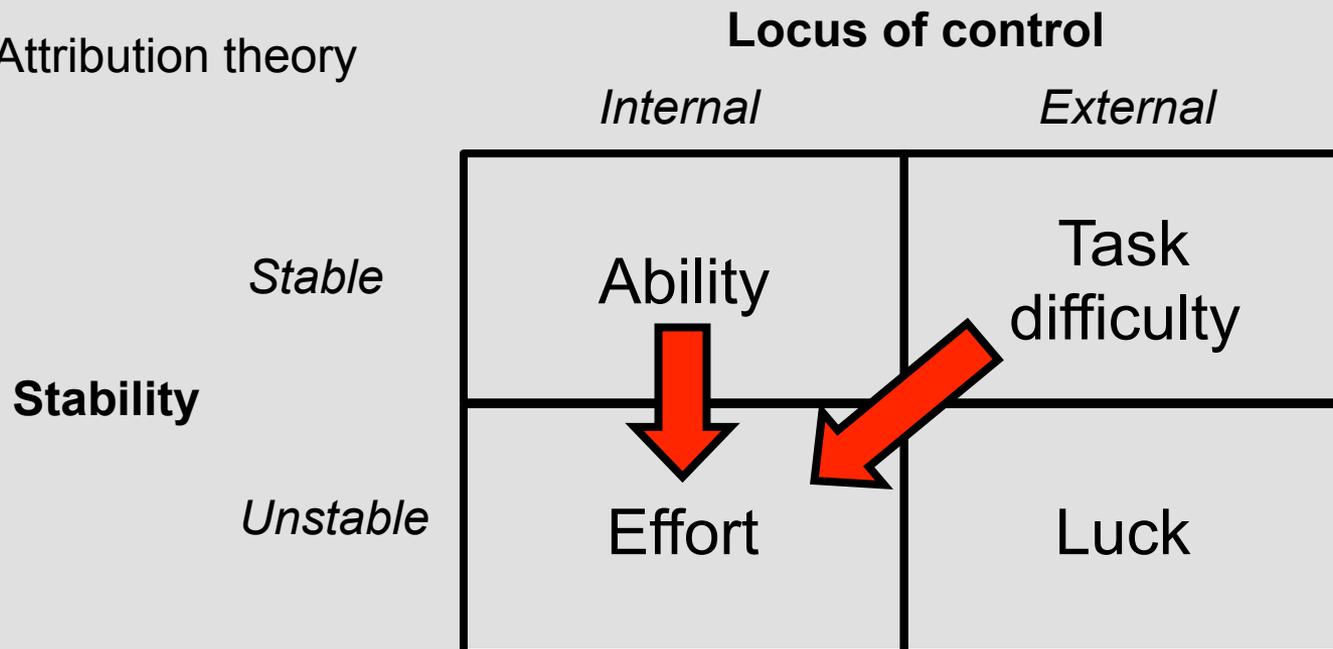
SECOND EDITION

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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.

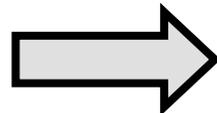
- Attribution theory



Is Active Learning Effective?

Is Active Learning Effective?

Many studies,
small Ns



Contradicting results,
non-significant findings

Study 1

Study 2

Study 3

Study 4

Study 5

BAKUR ÖZMEN, GÖRAN DEMIRÇELİK and RICHARD K. COLE

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

Received 7 April 2006; Accepted 28 June 2007

ABSTRACT. The research reported here consists of the introduction of an intervention based on a series of laboratory activities combined with concept mapping. The purpose of this intervention was to enhance student understanding of acid-base chemistry for high school students from two classes in a Turkish high school. An additional aim was to enhance student attitude toward chemistry. In the research design, two subsets of students were compared. One from the intervention group (30-31) and a second group (29-30) who were taught in a more traditional manner. The results of the study indicate that the intervention was effective (with an alpha reliability of 0.82) and the analysis of variance revealed statistically significant differences between the intervention and traditional groups with respect to conceptual understanding. Examination of student explanations and analysis of open-structured interviews conducted with selected students suggest that the main influence was the laboratory activities. Analysis of the findings in the context of relevant literature that concept mapping in conjunction with laboratory activities is more effective, helps student link concepts, and reduces their alternative conceptions.

KEY WORDS: acids and bases, chemistry teaching, concept maps, laboratory activities. According to constructivist learning theory, students begin studying science, not as "blank slates" but bring to the classroom or laboratory a variety of ideas of, and experiences with, natural phenomena that may influence their ability to understand different scientific concepts (Galla & Lincoln, 1989, 1994). Educational research suggests that students' world views about scientific phenomena, as well as often being different to the science conceptual views, may interfere with students' learning of other scientific principles or concepts (Palmer, 1999). Such views are nowadays more commonly referred to as student alternative conceptions: a tacit recognition that these views and ideas are logical, sensible, and valuable from the students' point of view, even if they differ from accepted scientific views (Chesson, 2004; Pádua, Tringali & Walkington, 2005). Research indicates that these beliefs are held by learners across different

p = 0.000

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

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p = 0.08

Concept mapping and verbal ability in chemistry. Concept mapping is a representational diagram (Novak, 1984) that organizes and represents concepts and their relationships. It is a tool for learning (Novak, 1979; Novak, 1984; Novak & Gowin, 1984; Novak & Johnson, 1983; Malone & Oskamp, 1984; Ault, 1985; Frazer & Edwards, 1987; Feldman, 1987; Fowler & Ben Jaccar, 1987; Barabási & Tamar, 1987). In this regard, the concept map may assist the student in relating new concepts to previous knowledge (Novak & Gowin, 1984). Research has shown a relationship between student concept mapping and achievement. Boninger (1982) found that skill in concept mapping predicted success on an achievement test among students in a college natural sciences class. In that study an significant difference in achievement was found between three groups who were taught different versions of concept mapping. Frazer and Edwards (1987) found that students who scored at high levels on end-of-unit tests showed high levels of concept mastery as indicated by the concept maps they made. At least three studies report performance differences due to student use of concept maps. Novak, Gowin, and Johnson (1983) describe a study where seventh and eighth grade students learned to use and apply the tool in a six-month trial. They found that students who had been taught concept mapping made more "valid

The Concept Map as an Advance Organizer

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Abstract

The objective of this study was to determine if a concept map used as an advance organizer can improve the scores achievement of eighth grade students. Eighty-four students in two classes were divided into two groups. One group used a concept map as an advance organizer and the other group did not. The results of the study indicate that the use of a concept map as an advance organizer was effective in improving the scores of the students. It is suggested that the concept map can provide to classroom teachers with a meaningful and practical structured approach for using advance organizers in their classes.

p ≤ 0.05

Schools are primarily interested in students being able to incorporate meaningful materials into their cognitive structure (Ausubel & Robinson, 1969). This is important, because learning an significantly better able to absorb and retain meaningful learning than rote learning. Ausubel (1963) points that meaningful learning occurs when new information is linked to existing relevant concepts in the learner's cognitive structure. Novak (1978, 1980, 1981) and Novak, Gowin, and Johnson (1983) have shown how this theoretical structure can be applied to developing a concept map which can be used as a practical teaching and learning technique. Concept mapping is an excellent device that visually represents the hierarchical relationships between concepts within the structure or segment of a discipline (Shwartz, VanKirk, & Rowell, 1979).

Concept mapping has been recommended for use in courses in physics and literature (Morris, 1953), chemistry (Novak, 1984), sociology and computer assisted instruction (Hesse-Fry, Corvelli, & Novak, 1984), reading (Gale, 1984) and social studies (Weiss, 1986). Although its use is recommended by many writers, there have been relatively few research studies which evaluated the use of concept mapping at the elementary and secondary school levels. The results of the few studies which have been carried out are contradictory. Novak, Gowin, and Johnson (1983) reported that given proper instruction in concept mapping a student of any ability level could construct a concept map. In as

Conceptual Change Strategies and Cooperative Group Work in Chemistry

Patricia A. Beall

Prince George's Community College

Abstract

p = 0.01
p = 0.04
p = 0.11
p = 0.01

This study compared a traditional concept mapping approach with a conceptual change in chemistry. The study was conducted with 100 students in a chemistry course. The results of the study indicate that the use of conceptual change strategies and cooperative group work was effective in improving the scores of the students. It is suggested that the use of conceptual change strategies and cooperative group work can provide to classroom teachers with a meaningful and practical structured approach for using advance organizers in their classes.

One of the most important factors in the development of physical phenomena is that science educators are now brought face-to-face with a direct and difficult challenge: how to design classroom instruction that effectively addresses individual students' preconceptions and changes their concepts to scientifically accurate understandings. Some researchers (Anderson & Smith, 1983; Osborne & Fryberg, 1985; Bell, 1978; Ragan, 1986) have convincingly demonstrated that young students can indeed be helped to construct accurate conceptions. Many of these successful experiments

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

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Participants

Participants were students from the freshman level general chemistry course for science and engineering majors (CHM 115) at Purdue University. Twenty students were recruited for the study. Ten students (control group) were from CHM 115A, a section in which concept mapping was not part of the curriculum, and ten (treatment group) were from CHM 115B, a section in which concept mapping was an integral part of the course. The students who participated in this course were traditional college students. While every attempt was made to balance the treatment and control groups with respect to gender, the treatment and control groups were not balanced with respect to gender. In the control group, there were 5 males and 5 females. In the treatment group, there were 4 males and 6 females. The students in the control group had not had any high school chemistry. The students in the treatment group had had one year of high school chemistry. Two students had taken one year of high school chemistry, four had taken two years, and one female had taken three years of high school chemistry. This activity students were included in the study.

The study was limited to ten students from each section of CHM 115 as we could focus on student depth and breadth of knowledge. Had more students been included, we could not have developed such a detailed picture of each student's understanding of these concepts. Only one of our goals was to determine how instrumentalized student concept maps were to determine how qualitative the findings to support a more detailed and accurate representation of students' knowledge. While this limits the generalizability of the findings, it was a key feature of this investigation.

Course Design

The professor who taught the treatment section of CHM 115 used concept maps in lecture, during recitations, and in laboratory. The professor who taught the control section did not employ concept maps at all. Students in the treatment group used concept maps for the entire course, not just for the topics dealing with acids, bases, geometry, and stoichiometry. Students were trained at a faculty meeting at the start of the semester in constructing concept maps. Afterwards, they constructed concept maps as part of their homework assignments and papers. They also worked in groups during recitations to construct concept maps and to discuss their concept maps. Students' concept maps on gases and kinetics were evaluated.

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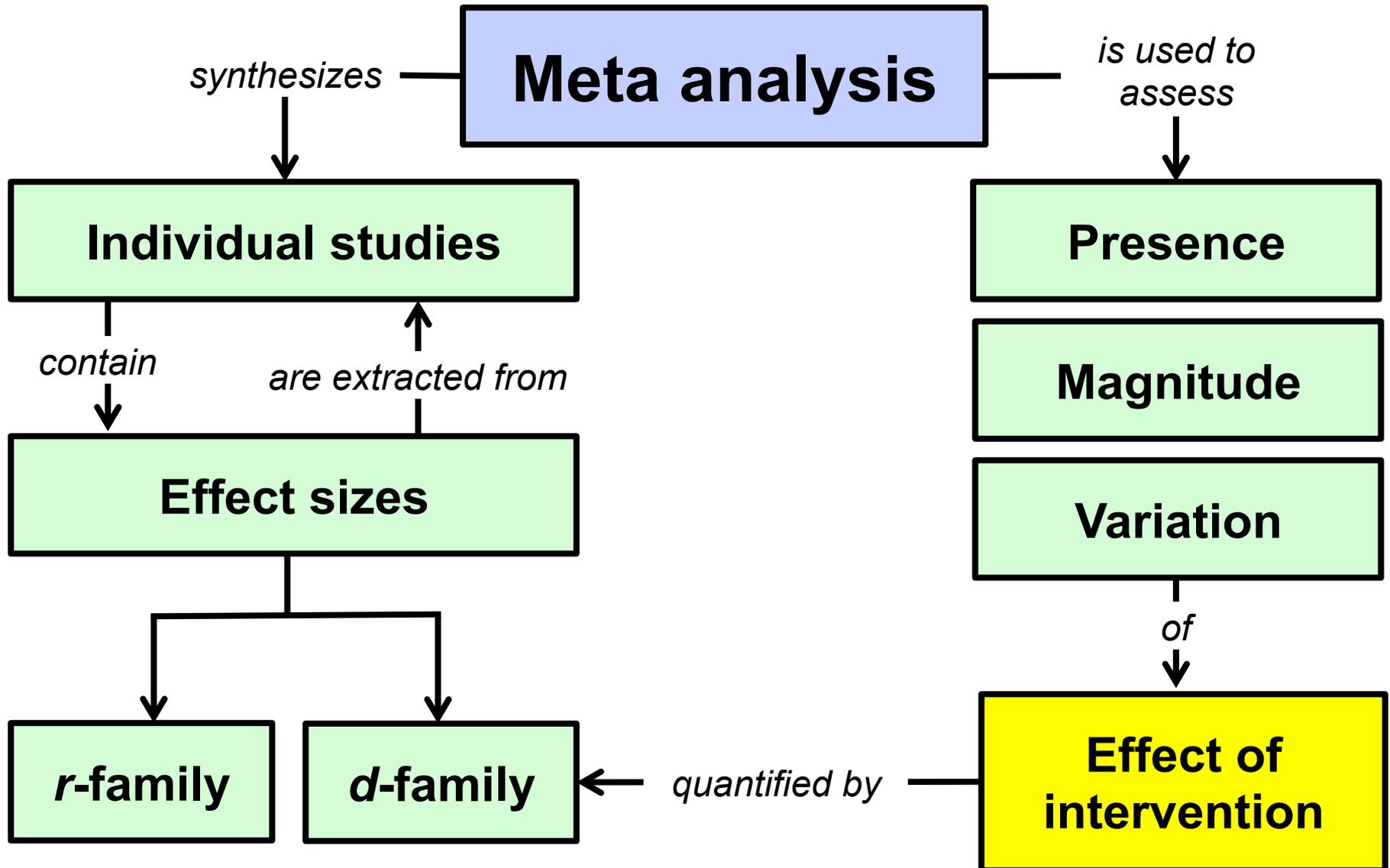
What is a Meta-analysis?

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)

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

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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 ($Z = 9.781$, $P \ll 0.001$)—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 ($Z = 10.4$, $P \ll 0.001$). 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.

Freshly available online through the PNAS open access option.

See Commentary on page R219.

To whom correspondence should be addressed. E-mail: rtf91@u.washington.edu.

This article contains supporting information online at www.pnas.org/lookup/suppl/doi:10.1073/pnas.1319030111/-DCS/Supplemental.

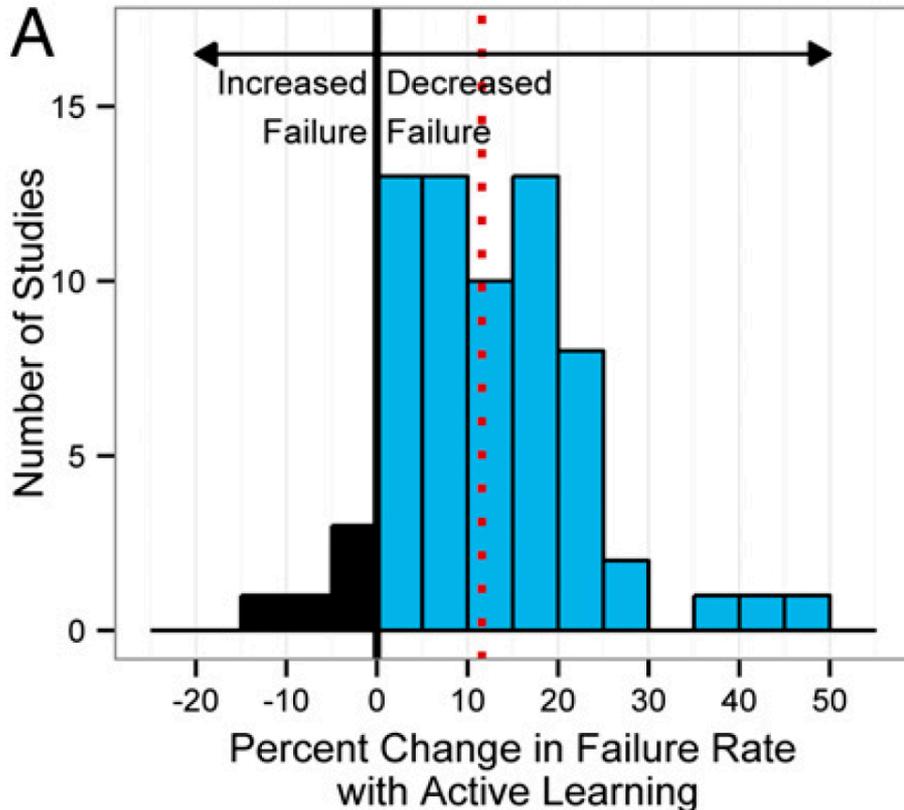
Meta-analyzed 225 studies that reported data on exam scores and failure rates in undergraduate STEM courses (traditional lecture vs active learning).

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.

Cited by 1141

Failure Rates



67 studies reported failure rate data

Average failure rate

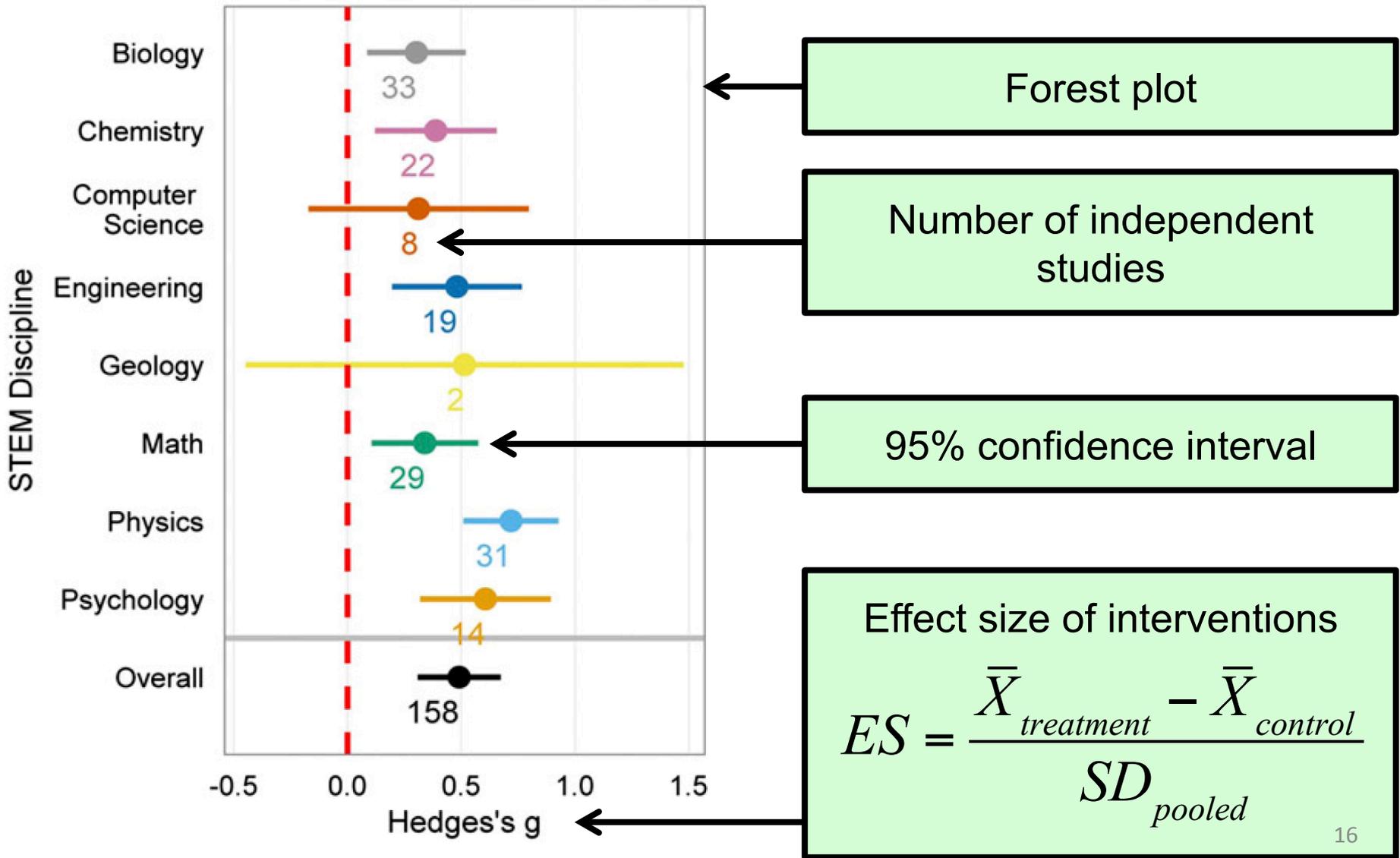
21.8% active learning

33.8% traditional lecture

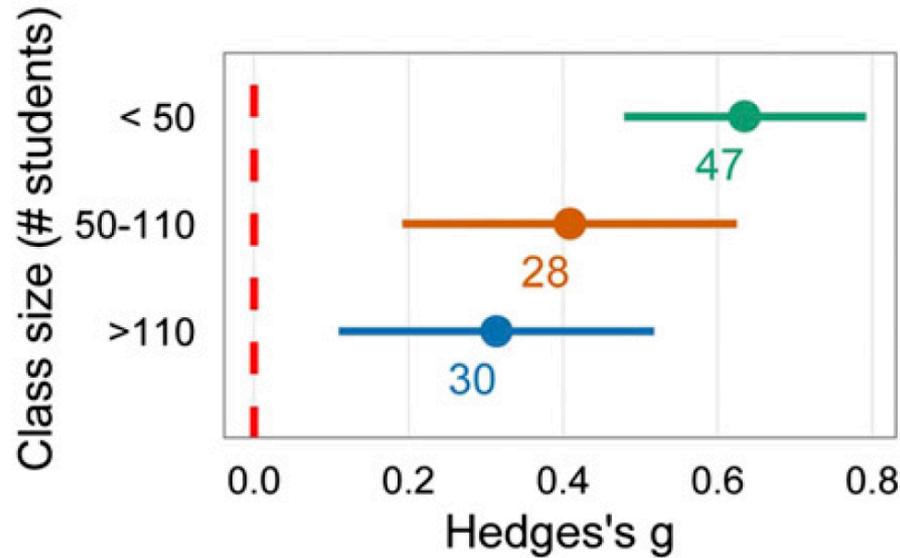
Risk ratio = 1.5

Students in lecture are 1.5x more likely to fail

Effect Sizes by Discipline



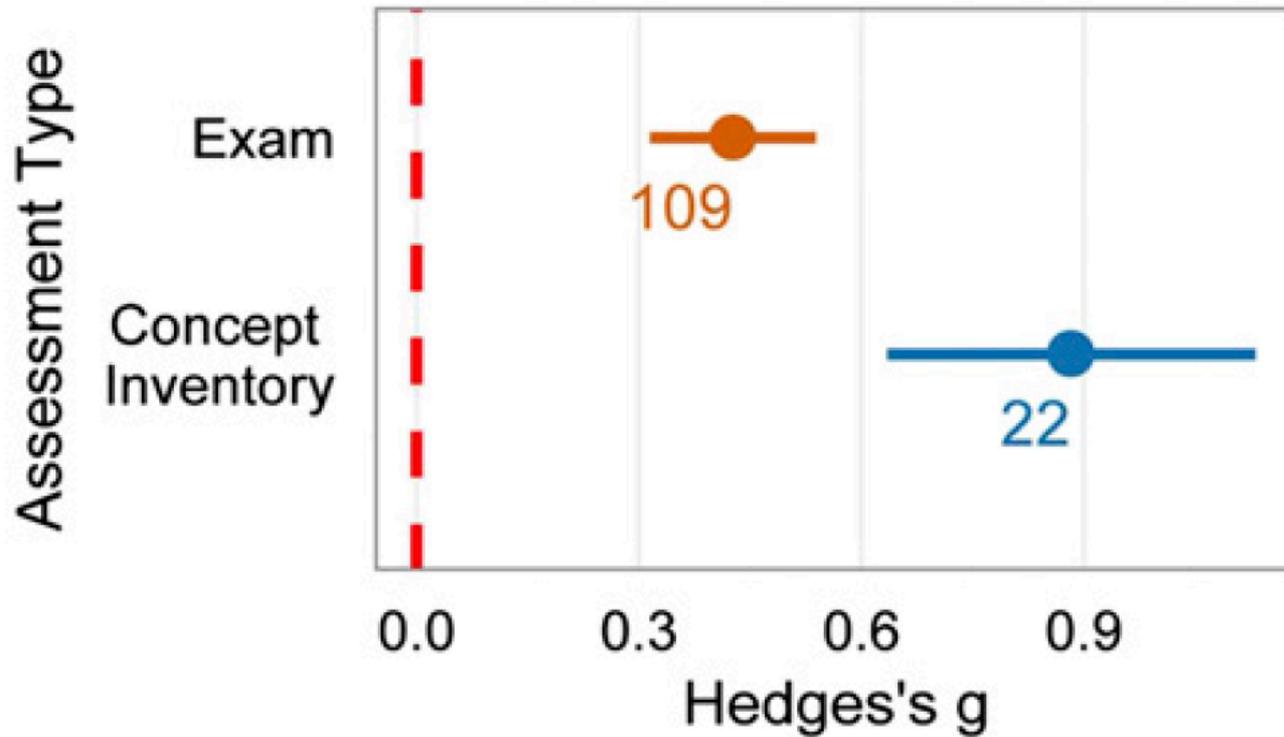
Class Size



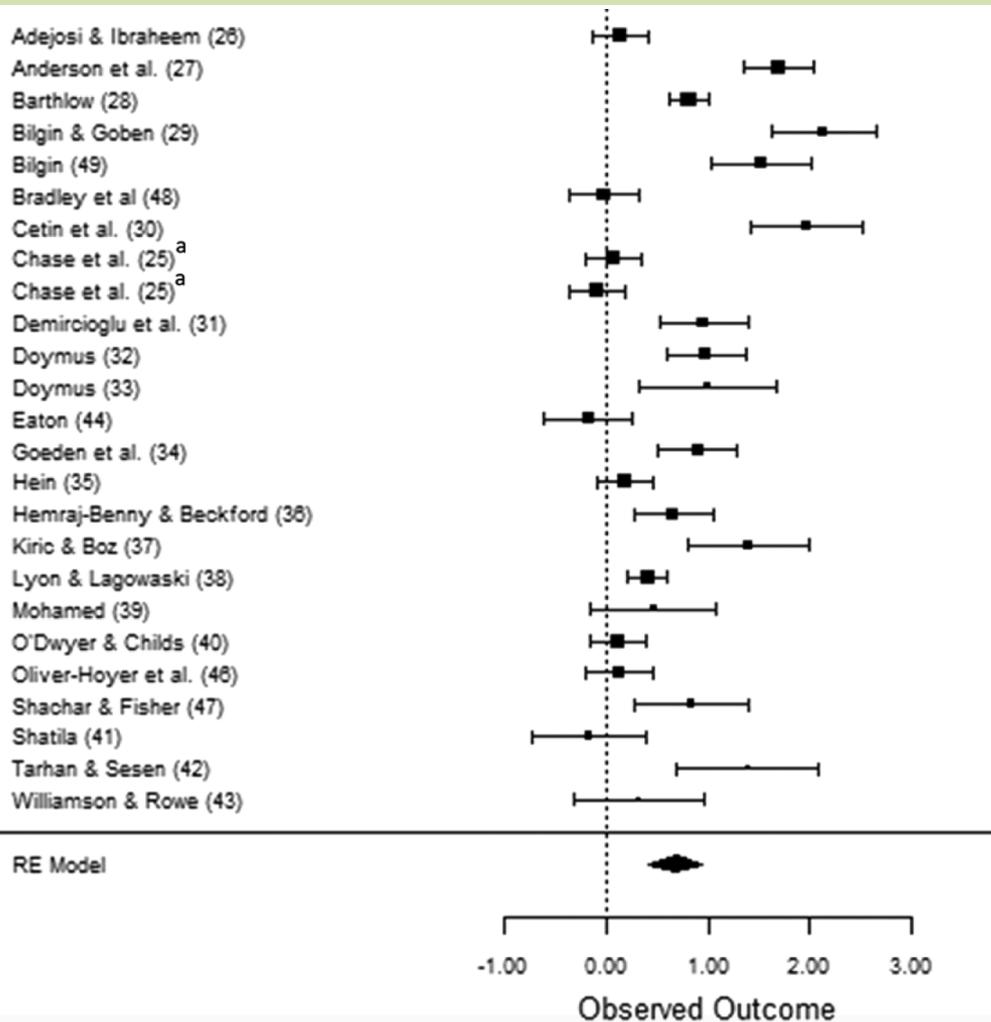
Poll Question: Which of the following can you conclude from this graph?

- 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

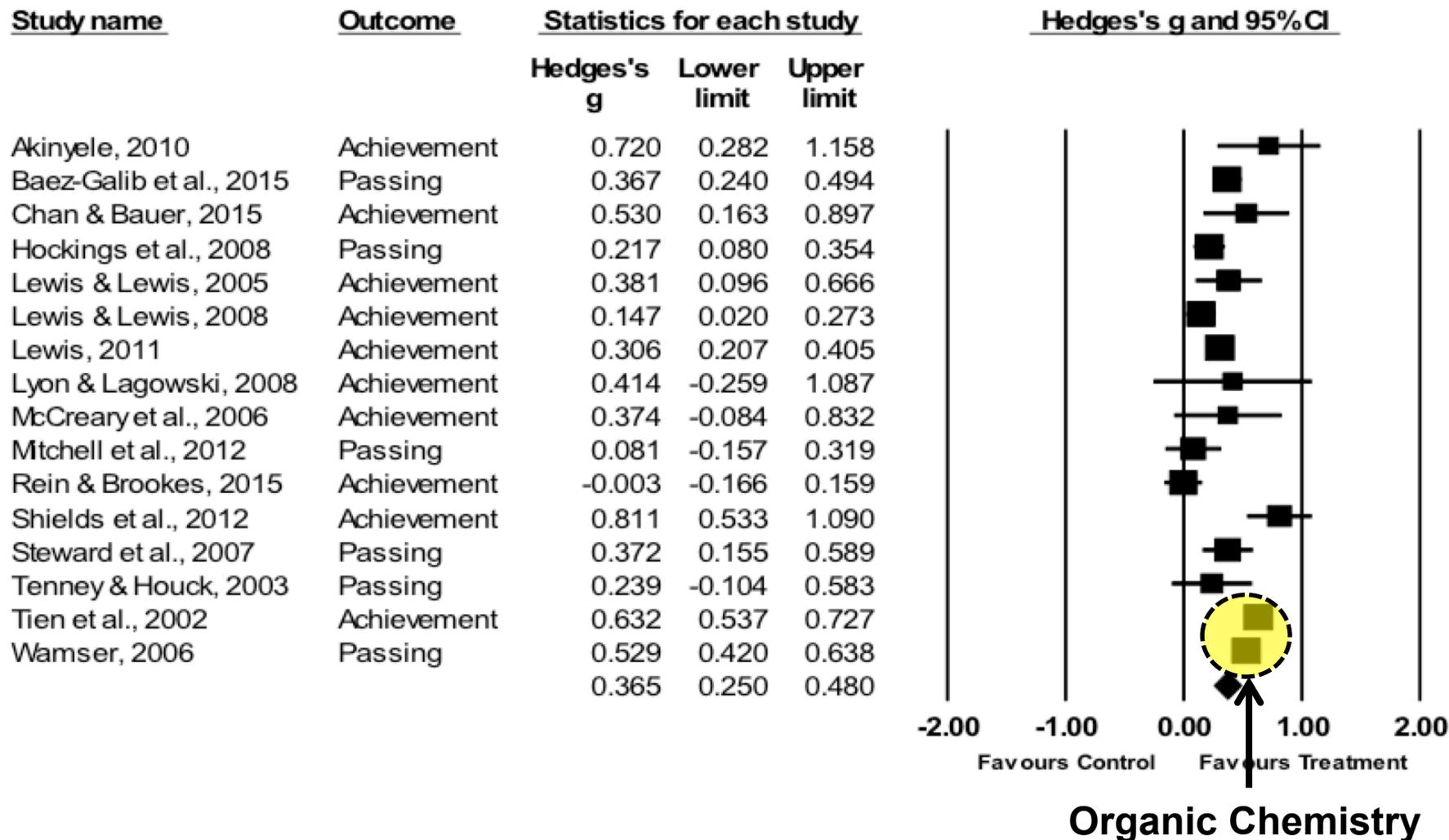


Meta-analyzed 25 studies that investigate the effectiveness of CL in chemistry.

$$ES = 0.68$$

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.

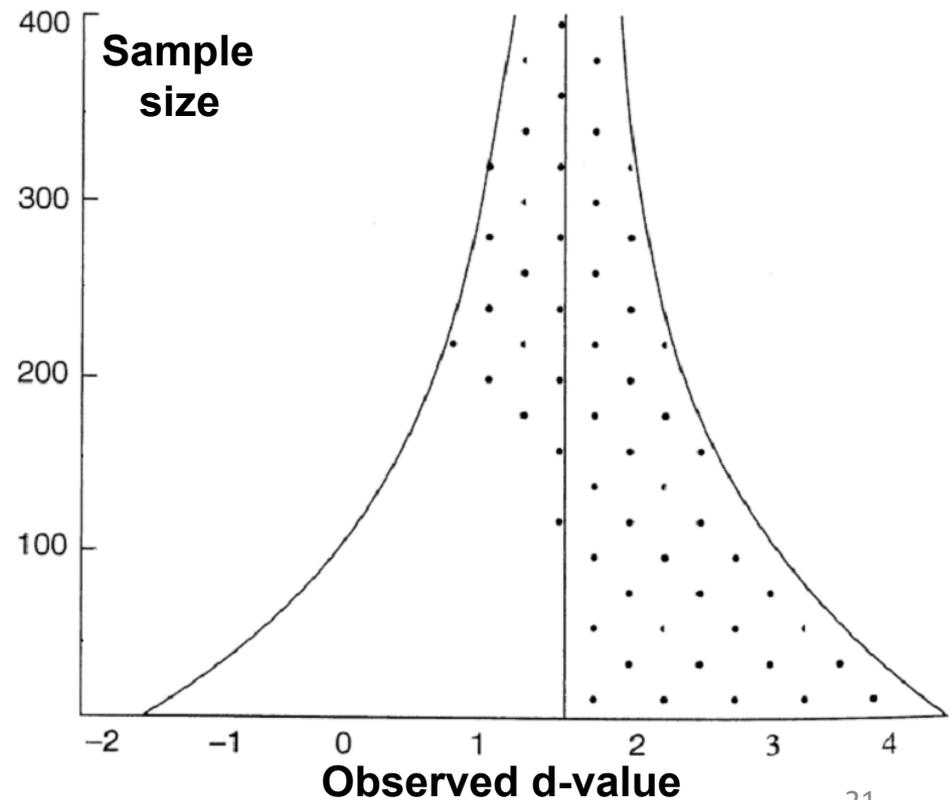
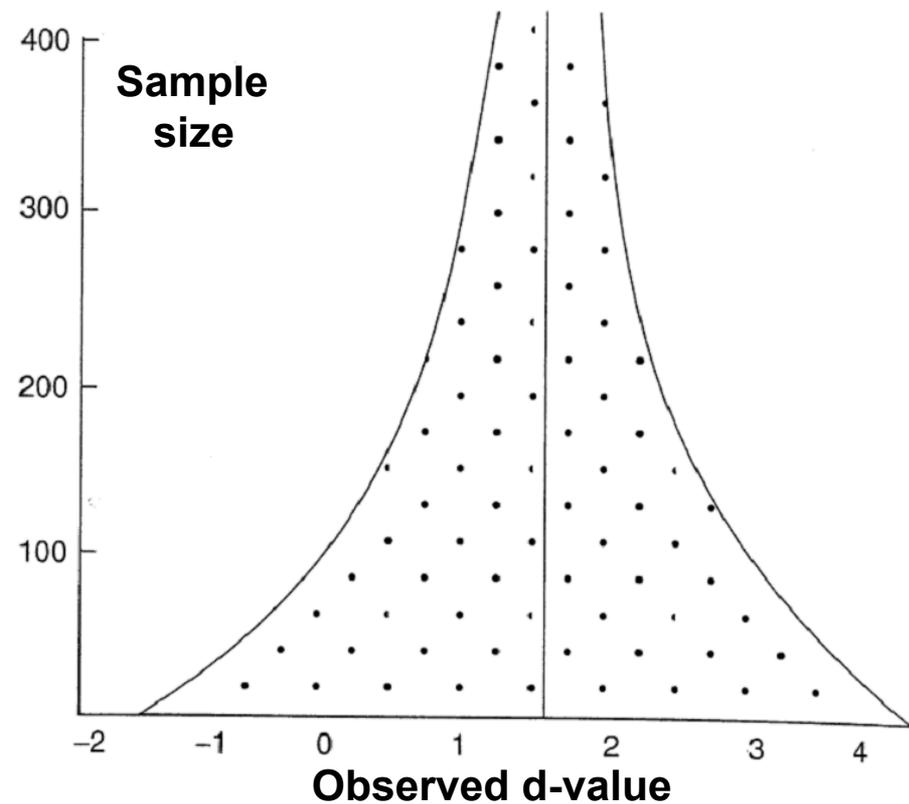
PLTL in Chemistry



Funnel plot

Symmetric

Asymmetric



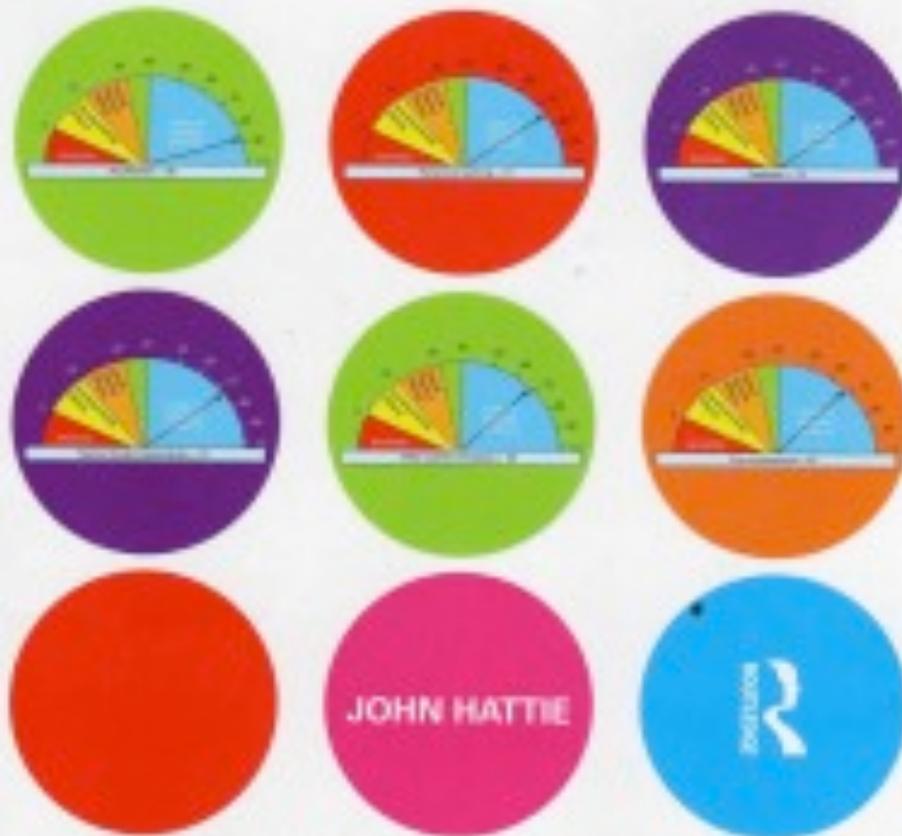
Where are small, non-significant studies?



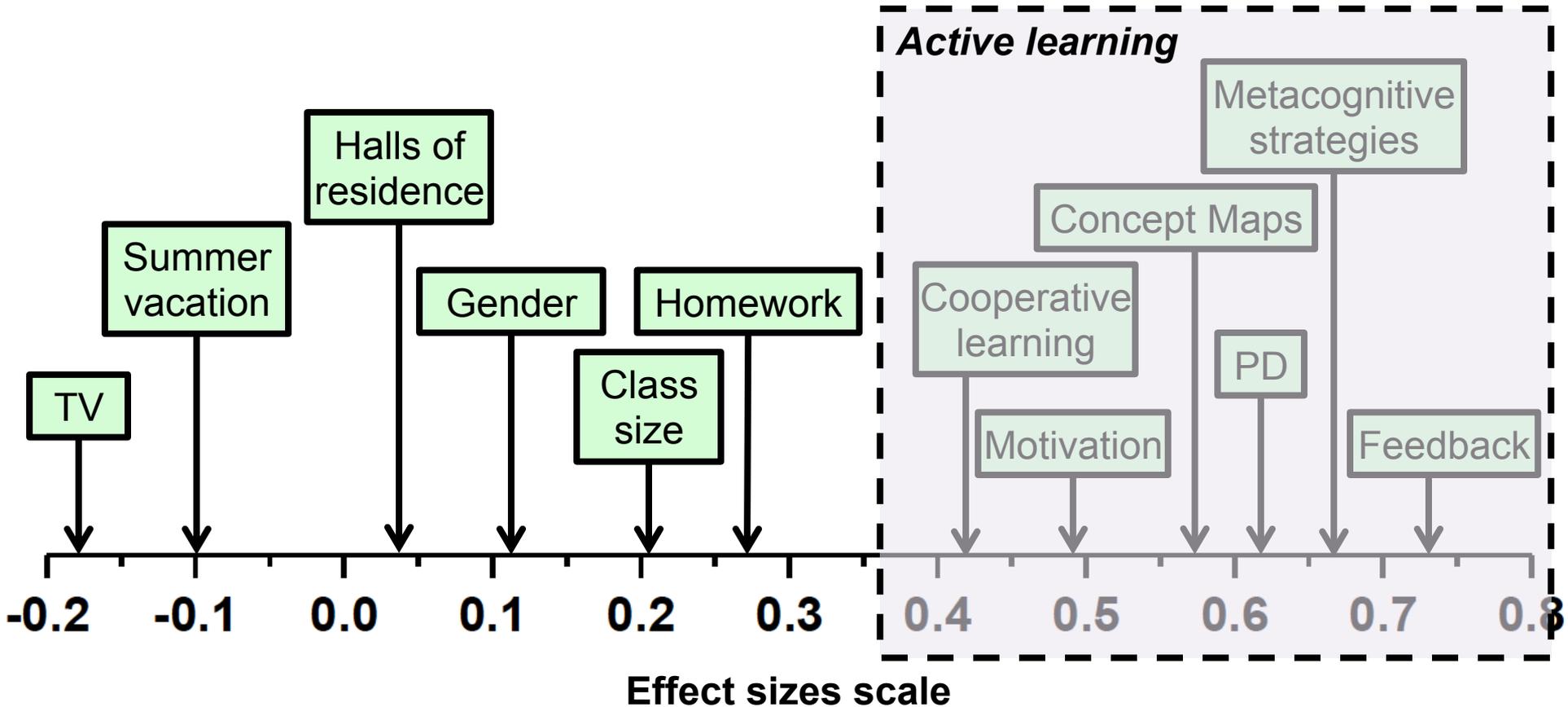
File drawer effect

VISIBLE LEARNING

A SYNTHESIS OF OVER
800 META-ANALYSES
RELATING TO ACHIEVEMENT



Effect sizes interpretation



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.

