Improving Science Pedagogy on Your Campus

Council of Independent Colleges

2022 Institute for Chief Academic Officers
with Chief Financial and Chief Enrollment Officers

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guidebook

Wiley University Services

Presenters

Amanda J. Brosnahan, Dean, College of Health and Science and Associate Professor of Biology, Concordia University, St. Paul

Benjamin Harrison, Associate Professor of Biology, Concordia University, St. Paul

Ian J. Rhile, Professor of Chemistry and Biochemistry, Albright College

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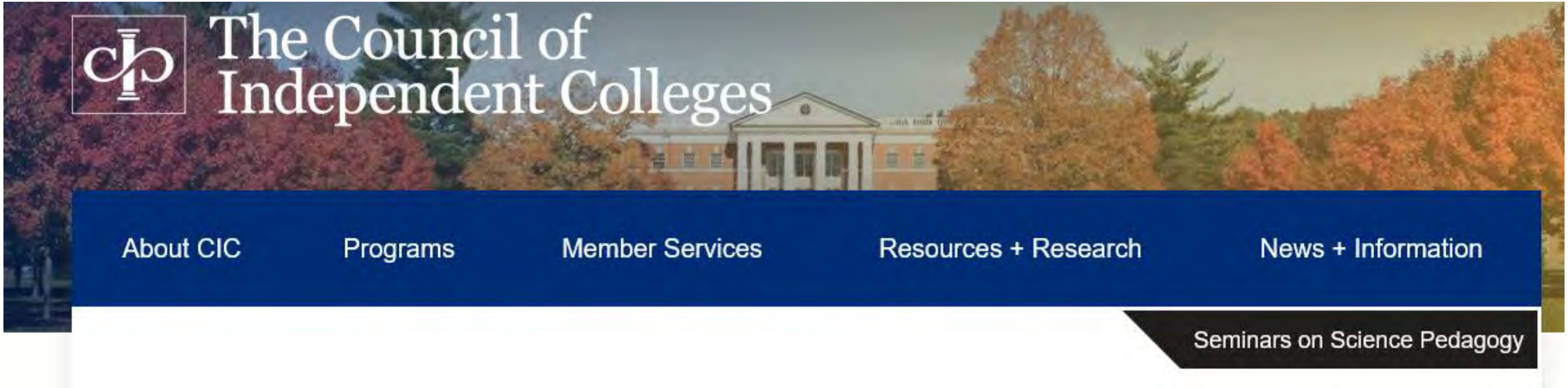
CIC



CIC Seminars on Science Pedagogy: July 2019 and July 2021

- Supported by a grant from the W.M. Keck Foundation
- CIC selected 9 institutions to participate each year
  - Each institution supported a team of 4 faculty
  - Extensive preparatory work prior to the seminar
  - At least 2 from each team taught at least 1 introductory course the following year, using methods learned in the workshop.

Goals: to improve teaching effectiveness and student learning in introductory biology, chemistry and physics.

Seminar methods based on research in cognition and neuroscience that have been shown to yield significant improvements in student learning in science at all levels.

Active learning model advocated by Stanford University physicist and Nobel laureate Carl Wieman, with colleagues at the University of Colorado at Boulder, the University of British Columbia, and Stanford.

Think-Pair-Share

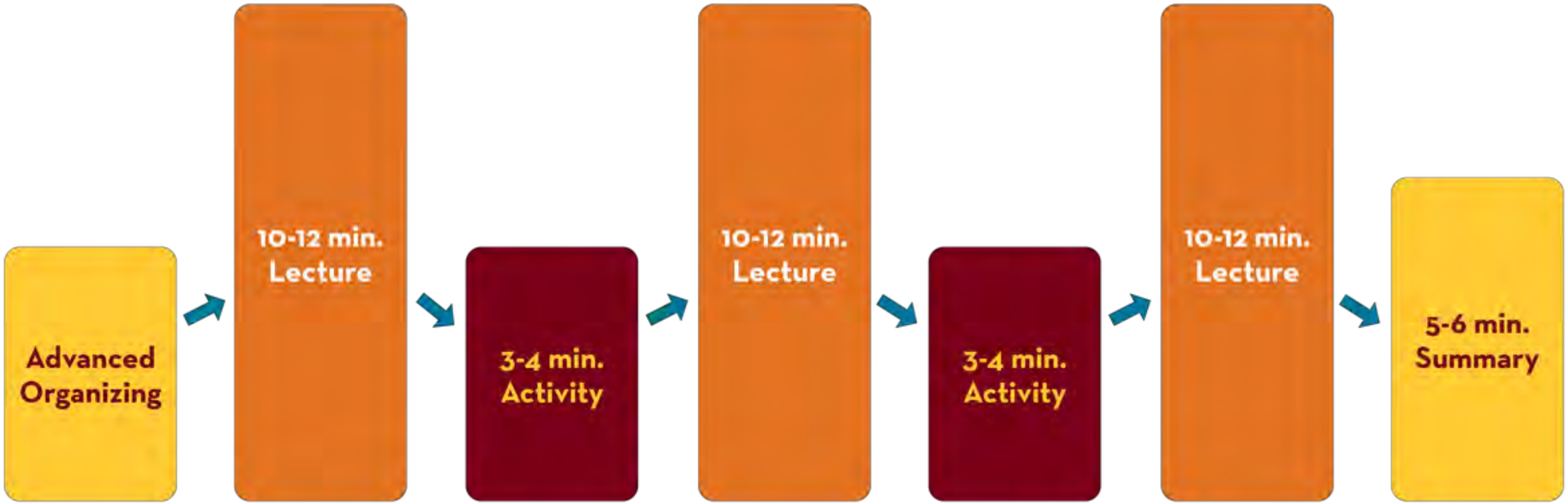
What do you know about active learning on YOUR campus?

What IS active learning?

Active learning activities vary from simple to complex.

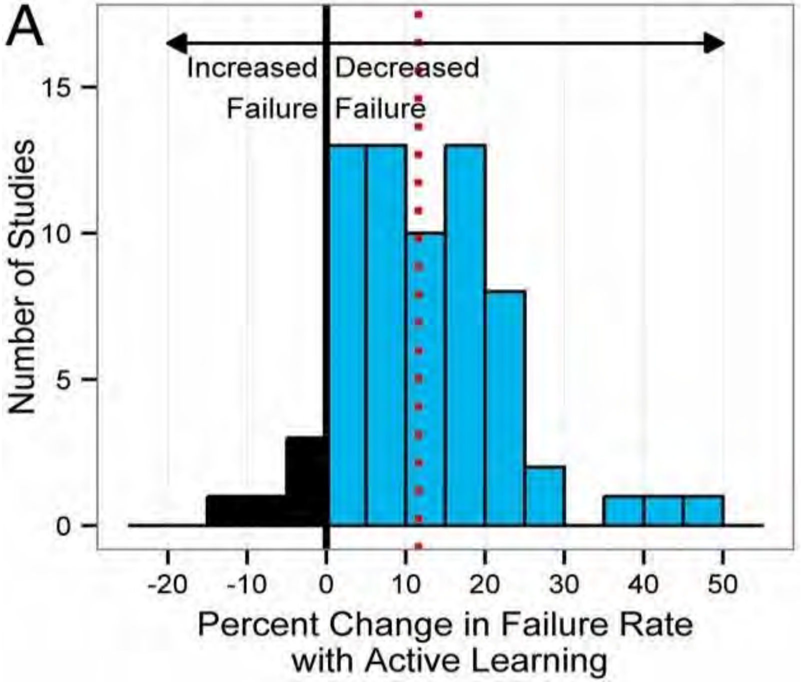
https://cei.umn.edu/teaching-resources/active-learning

Active learning can be interspersed with lectures.



https://cei.umn.edu/teaching-resources/active-learning

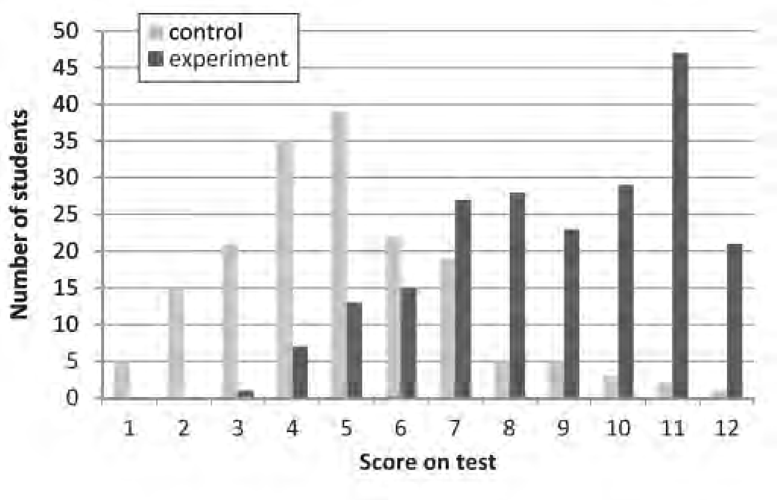
Active learning decreases DFW rates.

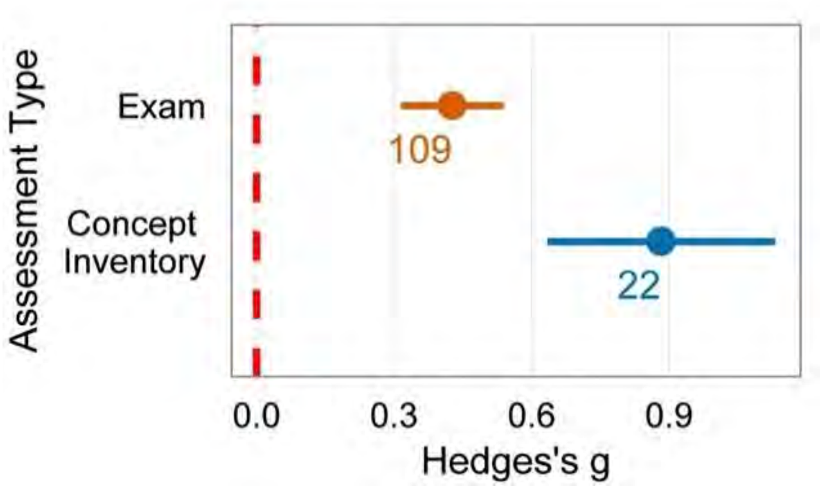


- Freeman et al. metaanalysis of 225 papers in 2014.
- Student performance improves by 0.47 SD.
- Students performing in the 50th percentile of a class based on traditional lecturing would, in active learning classrooms, move to the 68th percentile of that class.
- Average failure rates were 33.8% with traditional lecturing and 21.8% under active learning.

Freeman et al. *Proc. Natl. Acad. Sci. U. S. A.* **2014**, *111*, 8410-8415.

Active learning increases student learning.

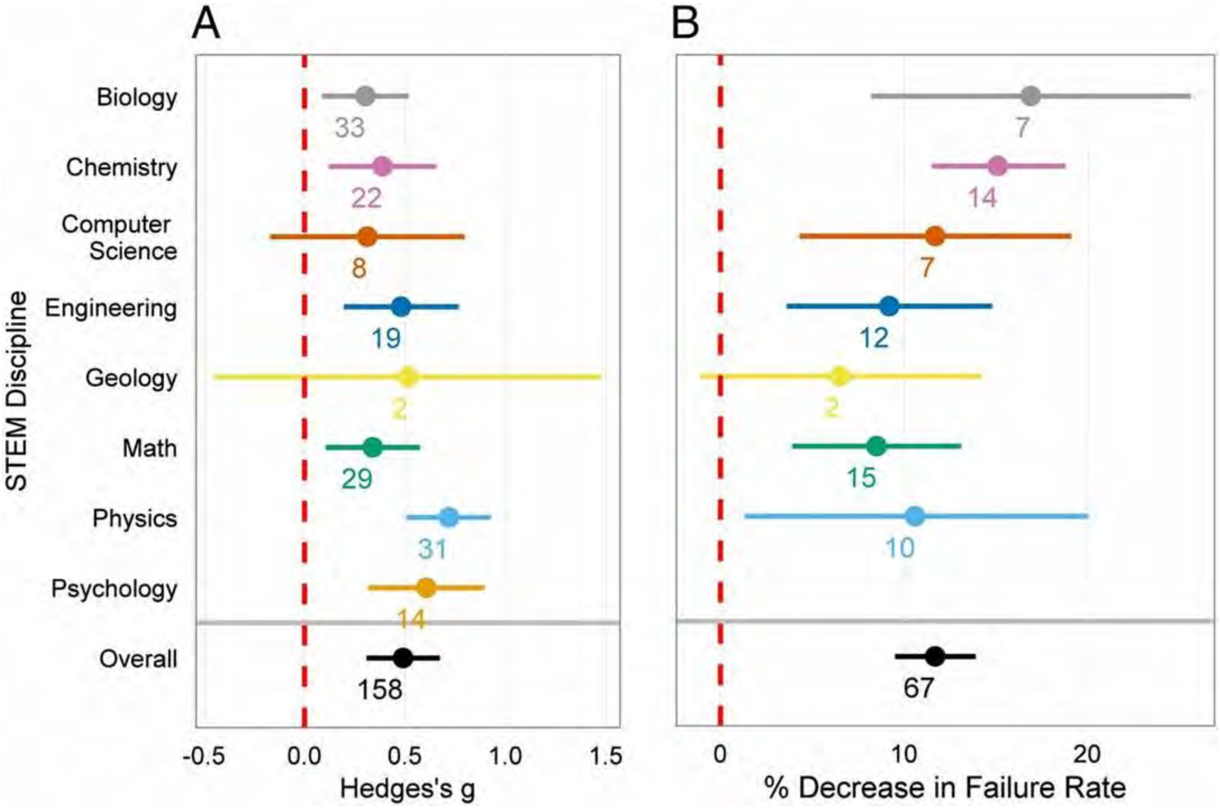




Left: Deslauriers et al. *Science* **2011**, *332*, 862-864.

Right: Freeman et al. *Proc. Natl. Acad. Sci. U. S. A.* **2014**, *111*, 8410-8415.

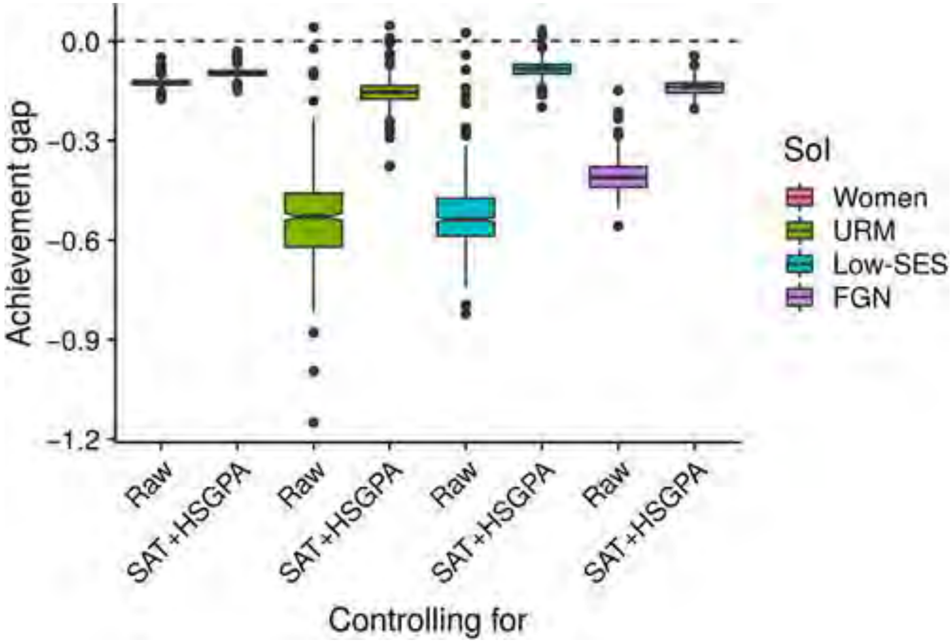
Active learning works across STEM disciplines.



Freeman et al. *Proc. Natl. Acad. Sci. U. S. A.* **2014**, *111*, 8410-8415.

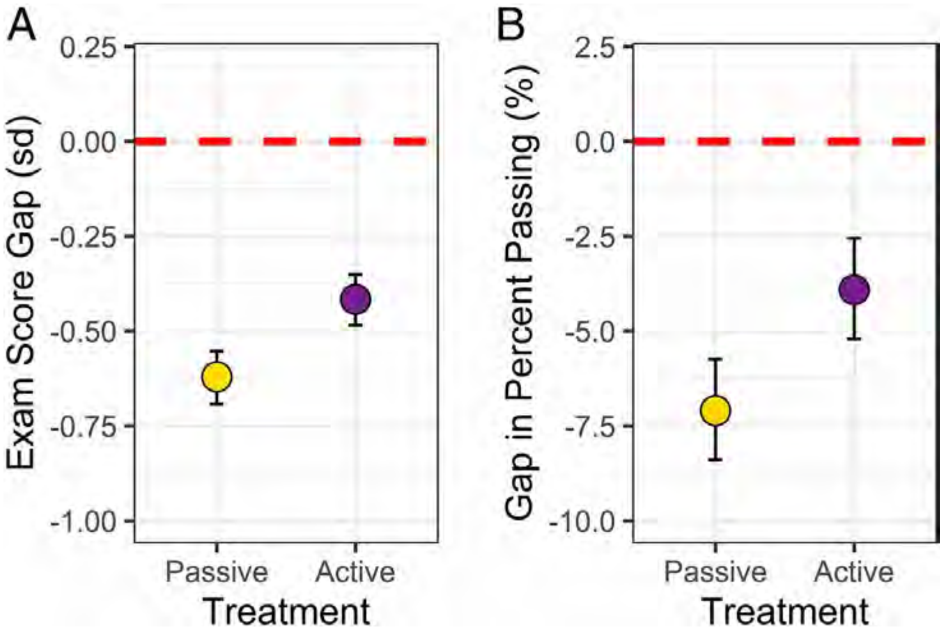
The achievement gap for underrepresented students is well documented.

- Of those who declare a STEM major, the percentage who earn degree is (2019):
  - 43% of Latinx students
  - 34% of Black students
  - 58% of white students
- Intro courses are important: underrepresented students are significantly more likely to persist with a C or higher in general chemistry 1.



Riegle-Crumb, C. et al. *Educ. Researcher*. **2019**, *48*, 133-144.
Harris, R. B. et al. *Sci. Adv.* **2020**, *6*, eaaz5687.

Active learning reduces the achievement gap for underrepresented students.



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Theobald, Elli J. et al. *Proc. Natl. Acad. Sci. U. S. A.* **2020**, *117*, 6476-6483.

Plenty of research beyond our own is emerging that backs up the idea that inclusive teaching strategies can get us closer to our collective goals around equity. One such example is a meta-analysis of published studies in STEM. Researchers found compelling evidence that the kinds of pedagogies that are inclusive (i.e., active learning) reduce differences between minoritized and non-minoritized groups, but only when 67-100 percent of total class time was spent on active learning (Theobald et al., 2020). **Thus, this kind of teaching is also an act of antiracism.**

Hogan K. A.; Sathy, V. *Inclusive Teaching, Strategies for Promoting Equity in the College Classroom* (emphasis added).

Albright College Chemistry and Biochemistry

ALBRIGHT COLLEGE 1856

- The department is interested in increasing retention, especially in general chemistry.
- The College has DEI goals for increase retention in underrepresented students.
- Active learning present but not systematic.

Dr. Amy Greene

Dr. Nicholas Piro

Dr. Ian Rhile

Dr. Matthew Sonntag

Historically, Ian used lecture and problem solving sessions in general and organic chemistry.

- Traditionally, I used lecture with some active learning, albeit not in a structured way.
- Both courses have embedded problem solving sessions (1 out of 4 class sessions).
- In addition to the CIC seminar, I attended the Active Learning in Organic Chemistry Workshop in Summer 2022.

2021 CIC Seminar on Science Pedagogy

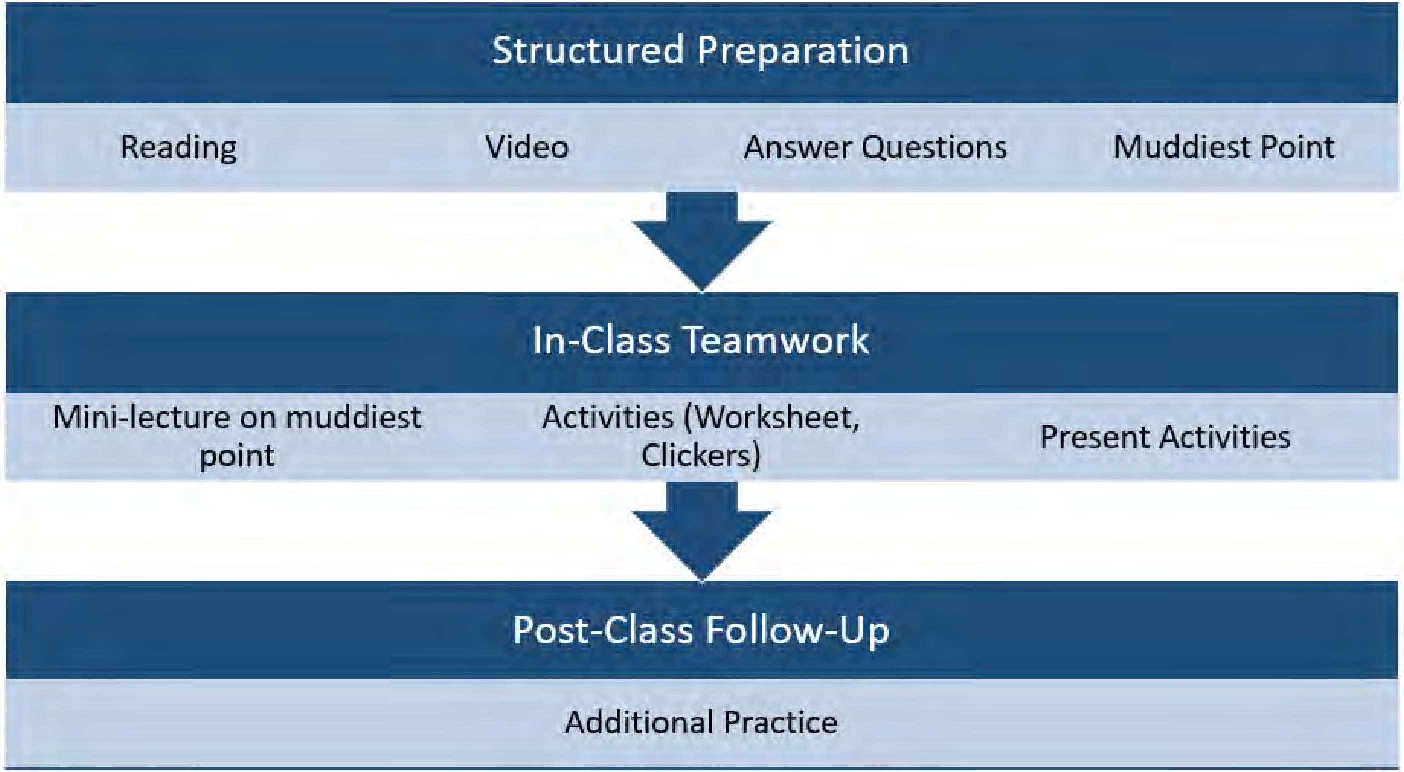
- Competitive proposal process
- 36 faculty from 9 CIC institutions
- July 12-16, 2021 (on Zoom, second offering after 2019 in-person)
- Topics include cognitive load, prior knowledge, deliberate practice, backward design, motivation, inclusive classroom, institutional change and others.
- Assessment from before the seminar and currently ongoing.

I have been using flipped format once per week for Organic Chemistry 1.

Flipped learning is a pedagogical approach in which first contact with new concepts moves from the group learning space to the individual space in the form of structured activity, and the resulting group space is transformed into a dynamic, interactive learning environment where the educator guides the students as they apply concepts and engage creatively in the subject matter.

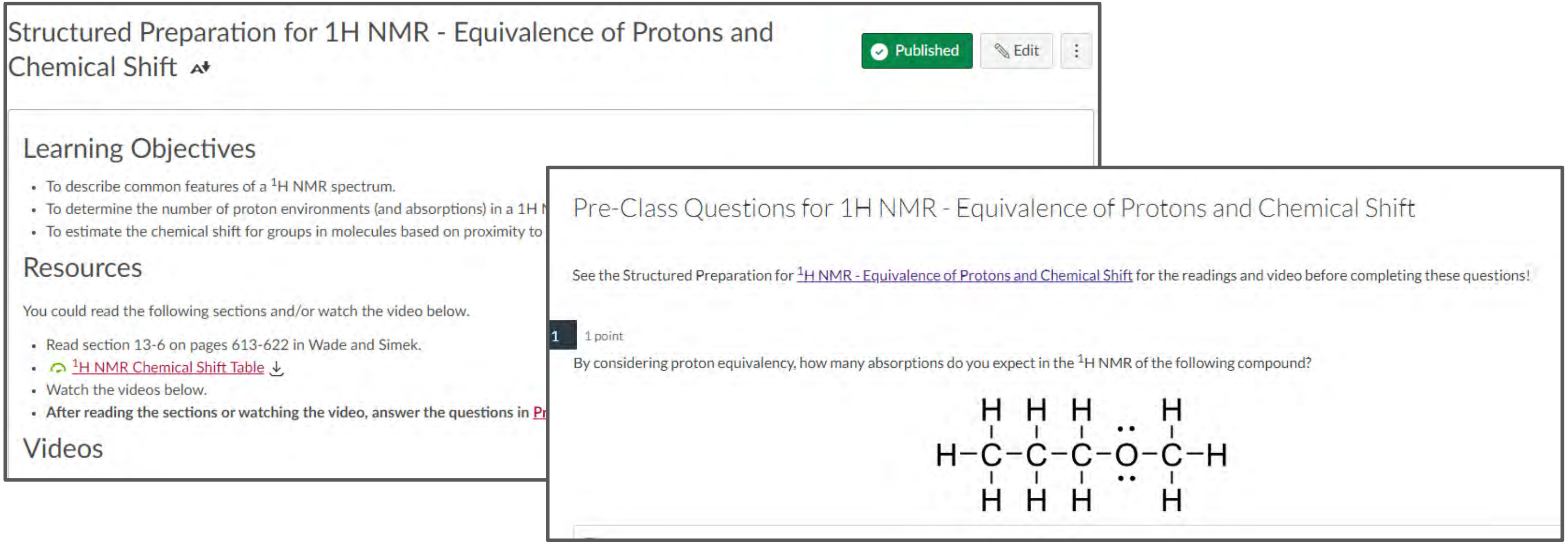
Talbert, R. *Flipped Learning: A Guide for Higher Education Faculty.* Stylus: Sterling, VA, 2017; p 20.

I have been using flipped format once per week for Organic Chemistry 1.



All activities are based on course learning objectives.

The preparation for flipped classes is structured.



- Last question: What questions do you have about the material?
- Due 2 hours before class
- The pre- and post-class work structures their preparation for class (“two hours outside of class for every hour in class”).

Class time is divided into three parts.

Answer questions about course content (10-15 minutes).

Work on activities in teams (20 minutes).

Report out on activities (10-15 minutes).

Reflections

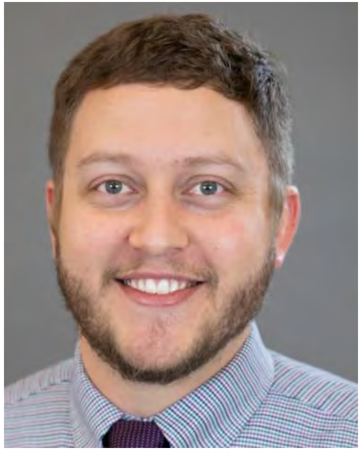
- In general, students seem more engaged and have more of a community identity.
- The students who receive the most benefit for grades seem to be those in the C/D range.
- Other instructors have used worksheets, extensive polling ("clickers") and gallery walk activities.
- Next steps: Some activities need tweaking; increase from one day per week to two or more!

The Science Department at Concordia University St. Paul

CSP SCIENCE

- Active learning had been a department focus for several years
- Elements of active learning had been integrated into almost every course
- We knew enough to know we could be better at using active learning techniques
- 4 of the 8 science faculty members attended the seminar: 2 chemists and 2 biologists

Dr. Taylor Mach
(Advanced Chemistry)



Dr. Matthew Jensen
(Intro. Chemistry)

Dr. Mandy Brosnahan
(Advanced Biology)

Dr. Ben Harrison
(Intro. Biology)

CSP's BIO120 (Intro. Biology)
Pre vs. Post CIC Science Pedagogy Seminar

Class "Preparation"

Chapter Reading (broad)

In-class Team Work

- Small Group discussion (informal)
- Activities (Drawing, Role Playing, etc)
- Sharing out (Large group discussion)

Post-class Practice

"Friday" Activities (peer-led), Online Review "Quiz"

Structured Preparation (Activation of Previous Knowledge)

- Targeted Reading
- Pre-lecture Quiz (easy)

In-class Team Work

- Brainstorming + Pattern Finding (Contrasting Cases and/or Venn Diagrams)
- Activities (Clickers, Discussion Questions, Drawing, Role Playing, etc)
- Sharing out (Large group discussion)

Post-class Practice

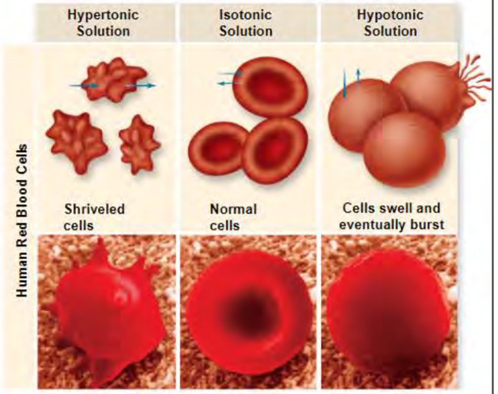
Drawing (less scaffolding, no notes), Mind Mapping, "Friday" Activities (peer-led)

CSP's BIO120 (Intro. Biology)
Pre vs. Post CIC Science Pedagogy Seminar

Pre: Classic lecturing - students passively listening

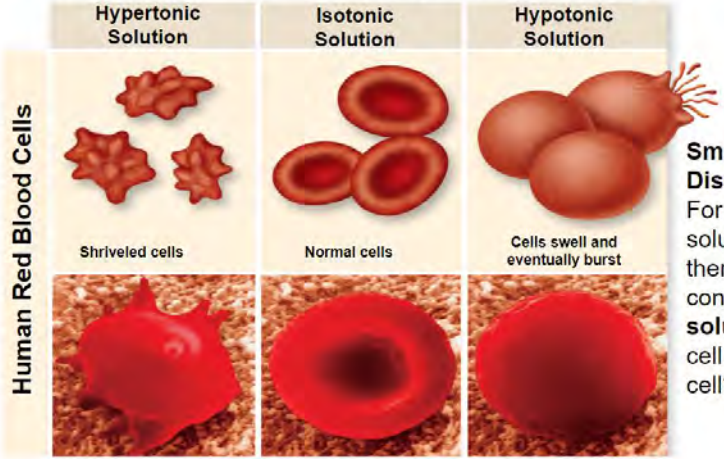
Osmosis

- A ***solute*** is any molecule dissolved in a liquid
  - Biologically relevant solutes include:
    - Salt ions
    - Nucleic acids
    - Proteins
- Cytoplasm has a number of different solutes in it
- When 2 solutions have different osmotic concentrations
  - **Hypertonic** solution has a higher solute concentration
  - **Hypotonic** solution has a lower solute concentration
- When two solutions have the same osmotic concentration, the solutions are **isotonic**



Post: Brainstorming, Contrasting Cases, Small Group Disc.

Membranes as Semipermeable Barriers (2-6)



Small Group Discussion:
For each type of solution, where is there a higher concentration of **solute** - inside the cell or outside the cell?

Unit 2 - Cell Structure, Membranes, Transport, and Signaling

#	Outcome	Bloom's Level	Study Approach
2-1	List three main components of the Cell Theory	1. Remember	Flash cards
2-2	Compare and contrast the features of prokaryotic, eukaryotic (animal) and eukaryotic (plant) cells.	4. Analyze	Flash cards/binning
2-3	Recognize eukaryotic organelles in an image.	2. Understand	Drawing
2-4	Describe the basic anatomy, and function of phospholipids.	2. Understand	Flash cards/Drawing
2-5	Draw out a membrane labeling hydrophilic (polar) heads and hydrophobic (non-polar) tails	3. Apply	Drawing
2-6	Describe what a semipermeable membrane is.	2. Understand	Drawing
2-7	Compare and contrast the 4 types of protein-dependent transport that take place across the membrane	4. Analyze	Flash cards/drawing
2-8	Describe the mechanisms of bulk transport across membranes.	2. Understand	Drawing
2-9	Compare and contrast the 4 different types of cell signaling.	4. Analyze	Flash cards/mind map
2-10	Describe the 3 major steps of cell signaling.	2. Understand	Drawing
2-11	Describe the 4 different types of receptors.	2. Understand	Drawing

Climbing Up the Ladder

	Intellectual Skill	Study Approach
Analyze	Seeing connections between mechanisms	Teaching/Explaining a concept to another person
Apply	How mechanisms relate to one another Describing a mechanism or process	Mind/Concept Mapping Drawing and labeling (without notes!)
Understand	Grouping terms or proteins into mechanisms	Venn Diagrams Listing/grouping terms together
Remember	Individual protein functions Term definitions Individual protein names	Organizing/boiling notes Flashcards Quizlets

Notice that re-reading text or notes and rewatching videos are off the bottom of this visual - they do **NOT** engage your brain enough to be considered studying!!!

Re-reading notes
Watching/rewatching videos

Ben’s Reflection on the BIO120 revisions so far…

- The construction of quality, focused learning outcomes has made decisions during the revision process a lot easier
- I feel we’ve finally putting the “Introductory” into Introductory Biology
  - Teaching students how to think and how to learn rather than an exorbitant amount of content
- Students are demonstrating better learning practices in class and out
  - Asking questions that indicate higher levels of understanding
  - Recognizing what they need to review and study
- While confounded by other revisions outside of new active learning techniques in class, our first exam had an average score that was ~10% higher than previous years

What do the majority of science classrooms look like at your institution?

A

Tiered, all facing lecturer boards/screens at front

B

Large group discussion, some boards/screens around room

C

"Pods", boards/screens surrounding classroom

Tiered, all facing lecturer boards/screens at front

Large group discussion, some boards/screens around room

"Pods", boards/screens surrounding classroom

I'm not sure

How can classrooms support active learning?

Classrooms to support active learning

Pods (or moveable desks)
Whiteboards (on walls or tables)
Space to move

Technology:
Microphones & speakers
Multiple monitors (1 per group)
*hyflex options?

Faculty development

- Look for opportunities to train interested faculty
  - Conferences, seminars, webinars
  - Observe others that already do it
  - Paired mentoring
- Provide resources
  - Course release for significant changes
    - If not possible, support incremental changes (Flipped Fridays)
  - Support faculty groups that want to explore together (Faculty Coffee Hours)
- Provide feedback and support
  - Observe their efforts.

How do you continue to support active learning efforts?

Monitor Instructor & Students every 2 minutes

Active learning occurring?

Main things looking for:

- Lecture/listening
- Posing questions/answering questions/asking questions
- Writing on the board
- Working in small groups (and mixing with those)
- Clicker questions

CBE—Life Sciences Education
Vol. 12, 618–627, Winter 2013

Article

The Classroom Observation Protocol for Undergraduate STEM (COPUS): A New Instrument to Characterize University STEM Classroom Practices

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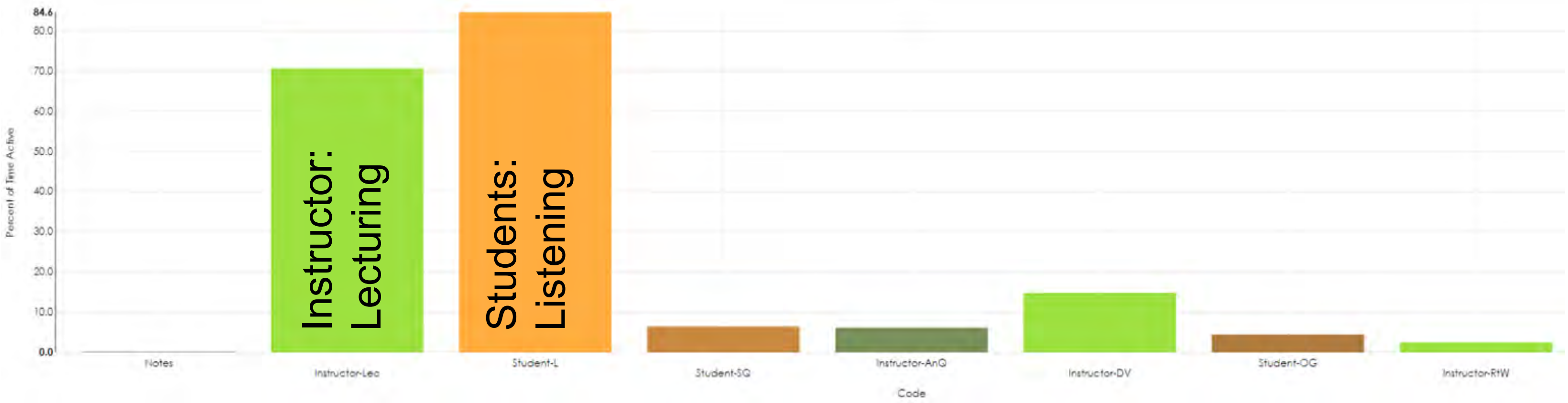
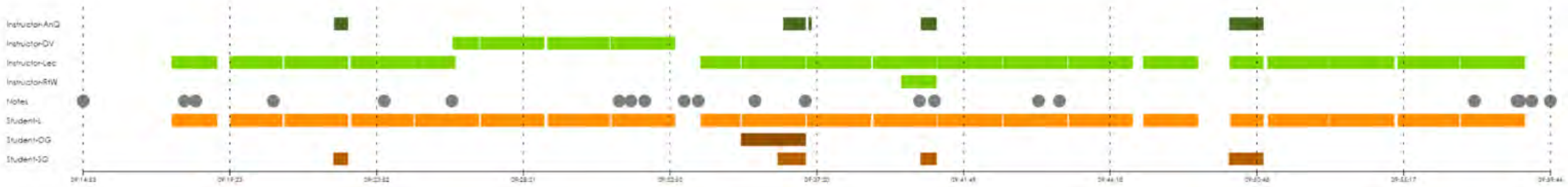
Submitted August 10, 2013; Revised September 8, 2013; Accepted September 9, 2013
Monitoring Editor: Erin L. Dolan

Instructors and the teaching practices they employ play a critical role in improving student learning in college science, technology, engineering, and mathematics (STEM) courses. Consequently, there is increasing interest in collecting information on the range and frequency of teaching practices at department-wide and institution-wide scales. To help facilitate this process, we present a new classroom observation protocol known as the Classroom Observation Protocol for Undergraduate STEM or COPUS. This protocol allows STEM faculty, after a short 1.5-hour training period, to reliably characterize how faculty and students are spending their time in the classroom. We present the protocol, discuss how it differs from existing classroom observation protocols, and describe the process by which it was developed and validated. We also discuss how the observation data can be used to guide individual and institutional change.

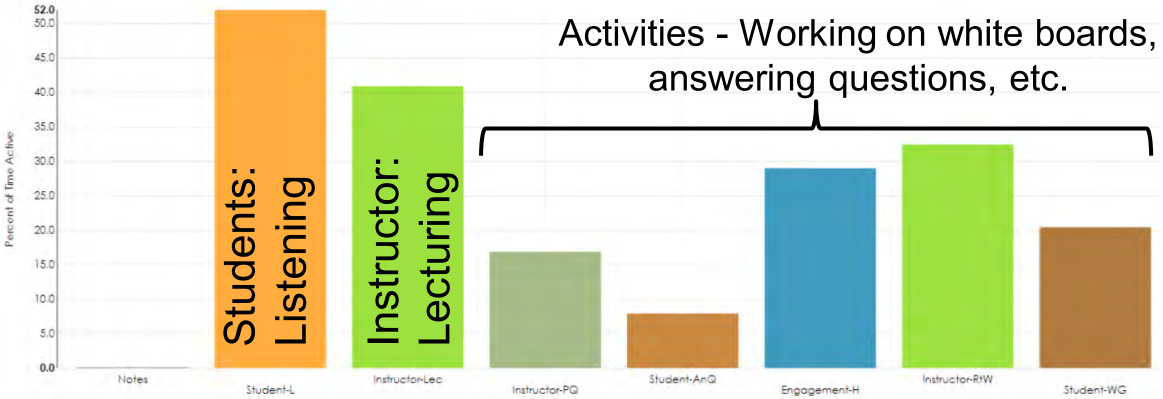
COPUS Data: Traditional Lecture



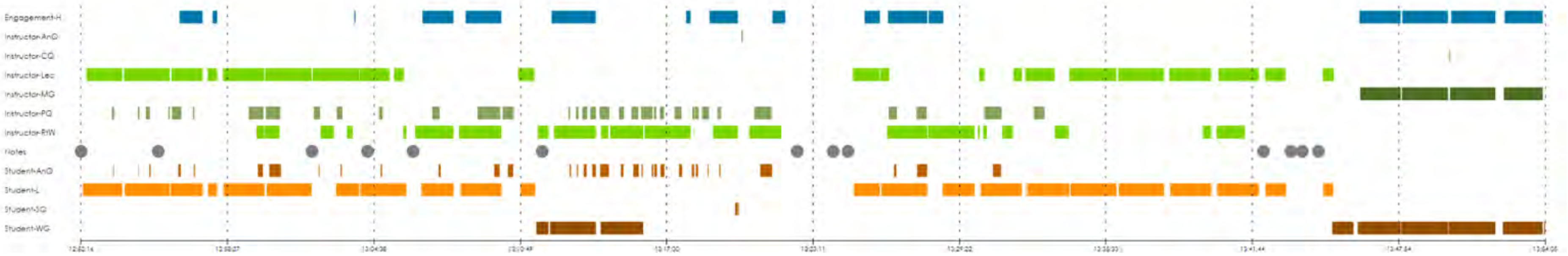


Class Timeline ⟶

COPUS Data: Active Learning



**A general goal for the average class meeting is lecturing in 10-13 min chunks broken up by 5-6 min of an active learning activity



Class Timeline ⟶

Think-Pair-Share

How might you better support active learning on your campus?

Resources (1)

- Ambrose, S. A.; Bridges, M. W.; DiPietro, M.; Lovett, M. C.; Norman, M. K. *How Learning Works, 7 Research-Base Principles for Smart Teaching.* Jossey-Bass, 2010.
- Deslauriers, Louis; Schelew, Ellen; Wieman, Carl. Improved Learning in a Large-Enrollment Physics Class. *Science* **2011**, *332*, 862-864; DOI: 10.1126/science.1201783.
- Freeman, S.; Eddy, S. L.; McDonough, M.; Smith, M. K.; Okoroafor, N.; Jordt, H.; Wenderoth, M. P. Active learning increases student performance in science, engineering, and mathematics. *Proc. Natl. Acad. Sci. U. S. A.* **2014**, *111*, 8410-8415; DOI: 10.1073/pnas.1319030111.

Resources (2)

- Harris, R. B.; Mack, M. R.; Bryant, J.; Theobald, E. J.; Freeman, S. Reducing achievement gaps in undergraduate general chemistry could lift underrepresented students into a "hyperpersistent zone". *Sci. Adv.* **2020**, *6*, eaaz5687; DOI: 10.1126/sciadv.aaz5687.
- Hogan, K. A. *Inclusive Teaching, Strategies for Promoting Equity in the College Classroom.* WVUP, 2022.
- Riegle-Crumb, C.; King, B.; Irizarry, Y. Does STEM Stand Out? Examining Racial/Ethnic Gaps in Persistence Across Postsecondary Fields. *Educ. Researcher* **2019**, *48*, 133-144; DOI: 10.3102/0013189X19831006.

Resources (3)

- Smith, M.; Jones, F.; Gilbert, S.; Wieman, C. The classroom observation protocol for undergraduate STEM (COPUS): a new instrument to characterize university STEM classroom practices. *CBE - Life Sci. Educ.* **2013,** *12,* 618-627. (Evaluations can be run online here: https://gorp.ucdavis.edu/)
- Theobald, Elli J. et al. Active learning narrows achievement gaps for underrepresented students in undergraduate science, technology, engineering, and math. *Proc. Natl. Acad. Sci. U. S. A.* **2020**, *117*, 6476-6483; DOI: 10.1073/pnas.1916903117.
- Wieman, C. *Improving How Universities Teach Science: Lessons from the Science Education Initiative.* Harvard UP, 2017

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guidebook

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